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Municipal Waste Combustion Systems Operation and Maintenance Study

Allen Consulting and Engineering, Cary, NC

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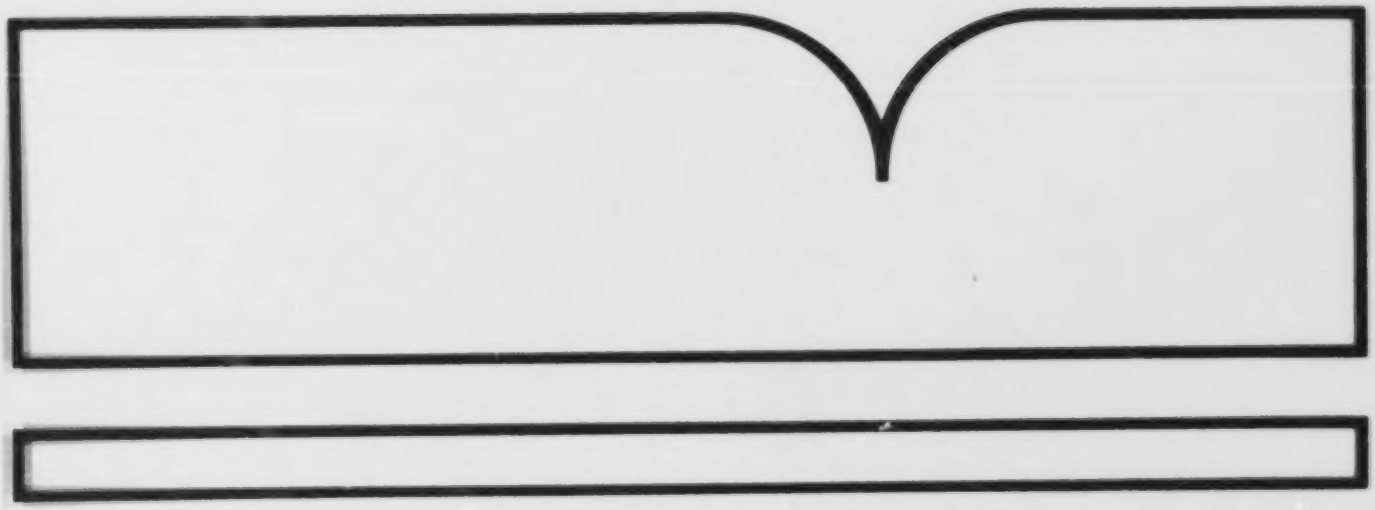

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16. ABSTRACT

This study was undertaken to determine the significant operation and maintenance (O & M) considerations that bear directly on the day in/day out air pollution compliance status of municipal waste combustors (MWC's). Two independent tasks were performed to compile and document these O & M considerations.

First, seven MWC sites were visited to interview equipment operators and management personal to determine the nature of the problems they routinely encounter in operating MWC systems. The information gathered from their visits is reported herein through a description of O & M problems and solutions for each major subsystem in the MWC process. The subsystems discussed include: fuel preparation and handling; furnace operation; ash handling; air pollution control equipment; fans, ducts and stacks; and procedural considerations such as startup/shutdown, equipment inspection, and recordkeeping.

Second, a field study was conducted to determine the effect of operating variables on visible emissions (opacity) at one facility. Ninety days of hourly readings of process and opacity data were collected by the MWC staff. An attempt was then made to statistically correlate the process and opacity data.

17. KEY WORDS AND DOCUMENT ANALYSIS

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CHAPTER 1

INTRODUCTION

Municipal Waste Combustors (MWC's) have traditionally had problems in complying with particulate matter and visible emission (VE) limitations and are often the subject of citizen's complaints. Due to stricter waste disposal regulations and decreasing availability of space for landfills, an increase in incineration is anticipated. It is believed that, in many cases, particulate matter and visible emissions of MWC's can be reduced by improving the incinerator and control equipment operation and maintenance (O&M) practices.

1.1 OBJECTIVES AND SCOPE OF THIS PROJECT

The objectives of this project were twofold. The first objective was to determine the significant operation and maintenance considerations that bear directly on the day in/day out air pollution compliance status of MWC's. Rather than performing theoretical analyses of furnace and air pollution control device performance, achievement of this objective was sought by visiting several MWC facilities and discussing the issues on-site with operators and management personnel.

The second objective was to determine the effect of operating variables on visible emissions (opacity) at one facility. Any correlation found would provide insight into the relationship between operating variables and opacity.

1.2 OVERVIEW OF MWC SITES VISITED

An attempt was made to select several facilities which, when taken together, would represent a reasonable cross-section of the types of equipment in service at the time of the visits (1985 and 1986). To keep travel costs to a minimum for the EPA headquarters and contractor's staff, site visits were limited to the eastern United States. Seven sites were visited with a total of 19 furnaces in operation. Table 1-1 summarizes the types of MWC's reviewed. Recent permit applications for construction of MWC's indicate that the fraction of operating MWC's that burn refuse derived fuel (RDF) and/or utilize boilers to recover heat will substantially increase in the future. Processing municipal waste into RDF is an operation that is often performed off-site and then trucked to the MWC facility. RDF processing facilities are outside the scope of this report.

TABLE 1-1

TYPES OF MWC's REVIEWED

No. of Furnaces	Type of Furnace	Continuous or Batch Feed	Fuel[a]	Boiler	Air Pollution Control Device	Throughput per Furnace (tons/day)
4	Rotary Combustor	Continuous	MB	None	ESP	300
2	Rectangular	Batch	MB	None	ESP	100
3	Rectangular	Continuous	MB	None	ESP	300
1	Rectangular	Continuous	MB	None	ESP	240
4	Rotary Combustor	Continuous	MB	None	Venturi Scrubbers	250
2	Rectangular	Batch	MB	None	Baffle Wall Scrubber	215
1	Rectangular	Continuous	MB	None	ESP	200
2	Traveling Grate	Continuous	RDF	Water Wall	ESP	300

[a]MB = Mass burn (unprocessed municipal waste)

RDF = Refuse Derived Fuel

1.3 REPORT ORGANIZATION

Chapter 2 of this report contains a discussion of general O&M problems, concerns, and procedures described by MWC operators during the site visits. This discussion covers the whole range of operations at MWC's from furnace charging and combustion control to ash handling and air pollution control equipment.

Chapter 3 contains two major sections. The first section describes eight brief case histories of specific O&M related air pollution problems and the solutions implemented by the MWC operators interviewed for this study. The second section describes the results of the study on the effect of operating variables on opacity. This discussion includes a description of the facility, the operating variables studied, and the analytical techniques employed. The chapter ends with some conclusions that can be drawn of the study's results. Finally, Appendix A contains a report of the audit performed on the opacity meter at the facility.

CHAPTER 2

GENERAL OPERATING CONCERNS

2.1 INTRODUCTION

This chapter discusses MWC operating concerns as described by MWC operators and their supervisors at seven facilities visited over the course of this study. The operating concerns discussed herein include operating practices, preventive maintenance requirements, and recordkeeping necessary to operate MWC's reliably and in compliance with air pollution emission limitations. The operating concerns are discussed on a unit operation or equipment basis starting with fuel preparation and ending with the stack.

2.2 FUEL PREPARATION AND HANDLING

Mass burn MWC's are those facilities that charge municipal waste to the furnace on an as-received basis. The alternative to mass burning municipal waste is to process the waste into refuse-derived fuel (RDF). The extent of processing waste into RDF varies from plant to plant, but usually it entails any one or combination of the following processes: magnetic separation, shredding, screening, and air classifying. Most RDF facilities produce a fuel that can pass through a 10 mesh screen (0.034 in. square), or coarser fuels that can pass through screens up to six inches square. The 10 mesh screen produces a fuel that can be fired in a tangentially fired furnace that is similar to units that burn pulverized coal. The coarser fuel is fired in various types of stokers, most commonly those with a traveling grate.

The objective of processing municipal waste into RDF is to create a uniform fuel by improving the fuel's important combustion parameters, e.g. size distribution and combustible content. Indeed, one of the major challenges faced by operators of mass burn furnaces is the wide swings in fuel quality that are inherent in unprocessed municipal waste. This subsection discusses operating procedures employed by MWC operators to deal with the difficulties imposed by burning unprocessed refuse in mass-burn furnaces.

2.2.1 Trash Composition

Table 2-1 lists a "typical" composition of municipal solid waste. Trash composition will vary among facilities depending on factors such as region of the

country, season of the year, and the extent a given facility accepts non-hazardous commercial and industrial waste. Design values for heat and moisture content of the waste will vary among facilities. Factors that effect the design valves include the nature of the waste anticipated for the specific facility and whether (and to what extent) the waste will be processed into RDF.

TABLE 2-1

TYPICAL COMPOSITION OF
MUNICIPAL SOLID WASTE

Component	Weight Percent
Paper, Other than Newspaper	25
Newspaper	14
Garbage	12
Yard Wastes	10
Glass, Ceramic, Stone	10
Metal	8
Cardboard	7
Wood	7
Textiles	3
Plastic Film	2
Leather, Rubber, Molded Plastics	2
Total	100%

Source: Reference 1

The combustion characteristics of any given truckload of waste may be substantially different than the design value or general composition guideline. For example, municipal trucks collecting household garbage and trash will deliver waste that has substantially different characteristics than the trucks for a specific commercial operation that deliver nothing but shredded paper or process (non-hazardous) waste from a plastic film or corrugated box manufacturer. Regardless of the source of waste, mass burn MWC operators are often challenged by extended periods of wet weather, when much of the material they are attempting to burn has been soaked by several days of rain.

2.2.2 Pit Operation

The fuel preparation and handling procedures discussed here apply directly to those continuous and batch furnaces that utilize gravity feed chutes that are loaded with an overhead crane from a sub-elevation trash pit. A properly sized pit and one overhead crane can serve up to four furnaces with a total capacity of over 1000 tons of refuse per day. Pit sizing is important to the efficient movement of raw trash through the facility. Considerations include not only the furnace capacity, but also the anticipated operating schedules for the furnace and the trash receiving operation. Undersized pits require that municipal waste be stored for significant periods of time in a pile either inside the receiving room if space is available, or outside. In either case, odor problems are likely to ensue.

Municipal waste arrives at the incineration facility via truck. The trucks are weighed prior to tipping their trash into the pits. Weigh records provide reasonably accurate data regarding the amount of trash processed over a week or more and such data is useful in establishing long term trends about the production of municipal waste for the area serviced by the incinerator facility. The scale data can also be used to estimate hourly or daily furnace throughputs, but these estimates are crude at best since they do not account for changes in the amount of trash in the pit.

The crane operator can make or break a successful MWC operation. The crane operator should constantly mix wet and dry refuse in order to produce "uniform" refuse; although he or she should keep some "wet" refuse in one area of the pit and some "dry" refuse in another area for emergency use when required by the furnace operator. Should it become necessary to go from feeding normal refuse to feeding either wet or dry refuse, the crane operator should do it gradually and give the furnace operator time to change the combustion conditions. Constant observation of incoming loads by the crane operator will give that person an idea of the condition of the storage pit at all times and the location of the wet and dry refuse.

The feed hopper serves as a funnel to direct refuse into the feed chute. To prevent bridging in many hopper designs, the crane operator must take care not to fill the hopper more than approximately one foot above the entrance to the feed chute.

When not feeding the incinerator units, the crane operator should utilize all his time mixing the wet and dry refuse in the pit. Large non-combustibles such as refrigerators, drive trains, etc. should be carefully removed from the pit. Some

facilities set such materials aside for a metal recovery contractor, others ship such materials to a landfill. If allowed to pass through the furnace, large non-combustibles may damage the grate system and/or the bottom ash handling equipment.

Similarly, certain excessively combustible items such as tires and large foam rubber items should be set aside for disposal by other means, as should any excessively large items such as chairs and couches.

The crane operator should also attempt to clean the bottom of the pit occasionally and should not just take the refuse from the top of the pit. The best method is to remove everything down to the bottom of the pit in one area, then another, and so forth. If possible this program should be used weekly. The purpose of periodically cleaning the pit to the bottom is twofold. First, the longer trash stays in the pit, the larger its potential for creating odor problems. Second, decay of municipal trash produces methane gas that becomes trapped in the waste pile. Thus, periodic turnover of the pile minimizes fire and explosion hazards.

The trash in the feed chute provides the seal between the combustion chamber and the pit room for a continuous feed furnace. If this seal is broken, the combustion chamber will draw large volumes of cold ambient air, thus upsetting the combustion process and creating significant air pollution until the seal can be re-established and until the furnace can return to normal operating temperatures. Therefore, the crane operator should never "get behind" a continuous furnace.

For a batch furnace, when the furnace operator determines that it is necessary to charge the furnace, a guillotine gate located at the bottom of the charging chute is briefly opened to allow the trash to fall to the furnace. It is important that this procedure be coordinated with the crane operator to ensure that trash is available in the chute and that the gate is open for the minimum time necessary so that as little cold, ambient air as possible is drawn into the furnace.

Many facilities maintain a backup crane so that the facility can operate when the primary crane is down for maintenance. In a one crane operation, even as little as one hour of crane downtime may require initiation of shutdown procedures.

2.3 FURNACE OPERATION

The objective of MWC operation is to reduce the volume of municipal waste that eventually will go to landfill to the maximum extent practicable. This objective is achieved only when the MWC is operated in a manner that provides good combustion. Good combustion requires maximizing the classic three T's of

combustion; time, temperature, and turbulence. As discussed below, the MWC operator has meaningful control of only temperature; residence time and turbulence having been maximized through the design process.

This section discusses operating practices commonly utilized to provide good combustion at MWC facilities. Common upset conditions are described, as are operating procedures to minimize the impact of such upsets. The reader should keep in mind that providing good combustion minimizes air pollution by minimizing the emission of unburned particles and maximizing the combustion of volatile organic compounds (VOC) that evolve from the municipal waste in the combustion chamber.

2.3.1 Combustion Air

Oxygen is necessary to complete the combustion reaction. Oxygen is introduced to the furnace as preheated or unpreheated ambient air. In order to completely burn combustibles in the furnace, it is necessary to provide combustion air in excess of the theoretical quantity required by stoichiometry to completely burn (i.e., oxidize) the waste. A minimum of 50 percent excess air is necessary to provide adequate turbulance of the volatile gases generated from heating the solid waste. In general, waterwall furnaces require excess air in the range of 50 to 100 percent excess air, while refractory furnaces require 150 to 200 percent excess air.

An insufficient quantity of combustion air cannot provide adequate oxygen and turbulence for good combustion. Such a condition produces increased emissions of carbon monoxide, unburned organic gases and soot. Curiously, too much combustion air also produces increases in soot, CO and organic emissions. The reason is that the increased mass flow of cool combustion air tends to lower the furnace temperature. In addition, this increased mass flow reduces the residence time of combustible gases in the furnace and has a tendency to entrain significant quantities of ash out of the furnace.

All the furnaces observed in this study provide combustion air through underfire systems and most also utilize overfire systems. A brief description of these systems follow.

Underfire Air - Underfire air is provided by a fan with airflow controlled by a fan inlet damper. The air is manifolded to several areas under the grates, where it is directed upward so that the air passes through the grates, refuse and ash. In some MWC's the operator can control the amount of air independently to various sections of the furnace.

Underfire air systems are designed to provide sufficient velocity (energy) to the underfire air so that the air penetrates the fuel bed. This provides intimate contact of combustion air with the solid, combustible material in the fuel, thus enhancing the combustion process. However, in addition to lowering the furnace temperature, excessive flow of underfire air has the velocity necessary to carry ash and unburned solid material out the furnace in sufficient quantities to create visible emissions and particle fall out problems.

Some incinerator systems utilize an air preheater to heat the underfire air prior to introduction into the furnace. A preheater is an air-to-air exchanger that utilizes the waste heat in the furnace exhaust gases. Preheated underfire air increases the flame temperature, thus improving the combustion and energy efficiencies of the system.

Overfire Air - Overfire air is introduced above the fuel bed via high velocity nozzles through the furnace sidewalls, perpendicular to the flow of fuel. Optimum combustion usually occurs when the overfire air is somewhere in the range of 40 to 60 percent of the total combustion air introduced into the system. However, operating experience (i.e., trial and error) sometimes dictates that the fraction of overfire necessary for optimum combustion will fall outside of this range in a given furnace. As for design purposes, overfire air is any air introduced that is not underfire air. Therefore, overfire air also includes air introduced for sidewall cooling (if any) and air in-leakage from sight ports, furnace cracks, etc.

The primary reason for introducing air over the fuel bed is to provide turbulance to the volatile gases that have evolved from the solid refuse fuel bed, thus improving the combustion of those gases. A secondary benefit results to the extent that lower underfire air velocities reduce the entrainment of fly ash and other solid material in the exhaust stream.

2.3.2 Temperature

Maximizing time, temperature and turbulence is essential for good combustion. Of these parameters, temperature is the only one that can be directly measured and also the only one over which the incinerator operator has reasonably direct control.

The temperature not only varies with position within the combustion chamber, but also varies with time at a given position. Most systems monitor the temperature (using a shielded thermocouple) near the roof at the exit of the combustion chamber. Operating temperatures at this location for most MWC's are

in the range of 1200° to 1850° F. MWC's with waterwalls tend to operate in the lower end of this range, whereas refractory wall MWC's operate in the upper end of the range.

Furnace geometry may indicate a need to monitor temperature in several locations. For example, in rotary kiln designs, the combustion chamber divides itself into a drying chamber, an ignition chamber, the rotary kiln, and finally a mixing chamber where the furnace gases undergo final combustion. Temperatures in such a case are often monitored at the exit of the ignition chamber and mixing chamber. The common operating ranges for these locations are 1600° to 1800° F and 1800° to 2000° F, respectively.

Furnace temperature is controlled by adjusting the combustion air supply. The details as to how this is done regarding the split between underfire and overfire air will vary among facilities. In general, high temperatures are reduced by increasing the air supply, i.e., quenching the furnace with cool air. Conversely, low temperatures are increased by reducing the combustion air.

Maintaining an adequate furnace temperature is absolutely essential to attaining complete combustion and minimizing air pollutants. "Adequate furnace temperature", in effect, is the maximum achievable temperature that is consistent with the long term mechanical reliability of the system.

2.3.3 Furnace Pressure and Draft

MWC's are always operated at a modest negative static pressure, approximately 0.2 inches of water. There are several reasons for this. First, operation under negative pressure eliminates emission of toxic combustion products through site ports, furnace cracks and so forth into the workplace and general environment. All gas leakage related directly to the furnace leaks into, rather than out of, the furnace. Second, positive pressure exacerbates a phenomenon called torching. Torching occurs when the flame propagates from the fuel bed downward through the grates. Localized conditions can cause occasional torching in any furnace, but operating under negative pressure minimizes the phenomenon and the resulting problems with heat damage to the grate system and the underfire air system.

In order to remove the gaseous combustion products from the combustion chamber, it is necessary to establish the proper furnace draft, which is done by balancing the airflows among the over and underfire air systems and the induced draft (ID) fan. The ID fan is usually located donwstream of the air pollution control

system. (Some MWC systems utilizing wet scrubbers have located the ID fan upstream of the scrubbers to minimize fan corrosion.) If the furnace generates more combustion gases than the fan can handle the furnace pressure goes positive and puffing of combustion products from the furnace enclosure can usually be observed. This condition often is caused by an excessive burn rate which can originate from an excessive feed rate or feed that has an unusually high combustible content.

2.3.4 Feed Rate

In continuous, gravity feed systems, refuse is piled up in the feed chute. Refuse in the chute provides an air-tight seal while the furnace is in operation. Refuse is drawn from the chute by the action of the grates, either rocking or reciprocating grates. Thus, the feed rate is governed by the grate speed. Traveling grate systems do not employ a gravity feed arrangement. With traveling grates, the feed chute dumps on to an auger that moves the refuse to the traveling grate. The refuse is transferred from the auger to the traveling grate by an air blast distributor. The feed rate depends on the speed of the auger. Augers and traveling grates are used in systems utilizing RDF.

Improper feed rates create a variety of problems. If the feed rate is too low, insufficient energy is available to maintain an adequate furnace temperature. If the feed rate is too high the furnace temperature can reach unacceptably high levels. In either case, the bottom ash will contain a significant quantity of unburned material.

The feed rate also affects the depth of the fuel bed on the grates. A fuel bed that is too thick will not allow proper penetration of underfire air. On the other hand, a fuel bed that is too thin allows underfire air to penetrate the fuel bed with velocities that are sufficient to entrain significant quantities of ash (and unburned material) thus creating opacity and downwind fallout problems. Excessive furnace temperatures also cause premature wear and structural problems (buckling, warping, etc.) of the furnace refractory and grate system components, as well as slagging. Slagging is discussed in Section 2.3.7.

2.3.5 Dealing With Fuel Problems

This section discusses procedures for controlling the combustion process when especially low or high combustible fuel, respectively, is introduced to the MWC. Despite the efforts of the crane operator, it becomes necessary from time to time to burn fuel that has less than optimal characteristics.

All the facilities visited during this study utilize automatic combustion control (trim) systems that employ the furnace exit temperature as the operating parameter that controls the combustion process. A signal from the temperature sensor is processed by a central controller that operates the dampers on the overfire and underfire air fans. The details of how such a system operates will vary from plant to plant, but basically, each system responds to high temperature excursions by increasing the volume of combustion air in the furnace. The additional air cools the furnace. Conversely, the response to low furnace temperature excursions is to decrease the volume of combustion air in the furnace. The MWC visited that utilizes heat recovery also automatically controls the feed rate based on steam demand. There is a trend for newer MWC's with heat recovery to employ oxygen trim systems similar to those utilized in coal-fired utility boilers.

MWC's trim systems will compensate for moderate swings in fuel quality. However, if especially poor quality fuel is fed to the furnace, it may be necessary for the furnace operator to operate the furnace manually until the combustion process has stabilized. Whether manual operation is required or not, the adjustments to poor fuel quality depicted below are appropriate responses to the fuel conditions described.

2.3.5.1 Wet Refuse and Low Combustibles

Burning wet refuse or low combustibles requires running a shallow fuel bed on the ignition grates and maintaining high underfire air pressures. This is often accompanied by a slight reduction in the feed rate in the case of wet fuel. The wet, or low combustible content, of the refuse will effect a reduction in furnace temperature; thus, increasing the underfire air may appear contradictory to the discussion in Section 2.3.2 where it was stated that a decrease in furnace temperature should be countered with a decrease in combustion air. A couple of points need to be noted.

First, especially with wet fuel, the refuse simply will not burn until it is dry. Running a shallow fuel bed with high underfire air ensures good contact and mixing of the fuel with the air, enhancing the drying process. Second, cutting back on the feed rate reduces the amount of heat consumed per unit time utilized to evaporate the moisture. If the low combustible fuel is not wet, the forge effect of the higher underfire air rate assists in oxidizing such refuse. However, it is not usually desirable to cut back on the feed rate as long as the dry refuse is reasonably porous.

Automated combustion control systems that control both the underfire and overfire air will throttle back on the overfire air as the underfire air is increased, thus minimizing the cooling effect of the increased underfire air.

2.3.5.2 Dry Refuse and High Combustibles

To burn dry, high combustible content refuse, it is necessary to maintain a high fuel bed on the grates and set a low underfire airflow while maintaining a high overfire airflow and reducing the feed rate slightly. Highly combustible refuse creates excess turbulence in the furnace. If this turbulance (which is normally good) is exacerbated by a high underfire airflow and a shallow fuel bed, significant quantities of bottom ash and unburned waste will be carried out of the furnace and ultimately emitted to the atmosphere. The potential for excess furnace temperatures is eliminated by maintaining high overfire airflow and reducing the feed rate slightly.

2.3.5.3 Undesirable Waste

The best solution for dealing with combustion problems resulting from undesirable waste is to prevent such waste from ever reaching the furnace. The kind of waste that is usually amenable to this solution is certain kinds of highly combustible waste such as rubber tires, mattresses and certain types of commercial and industrial waste.

Some municipalities do not allow neighborhood trash collection crews to pick-up tires. Such prohibitions often include items that can cause mechanical damage to the MWC such as large appliances, axles, engine blocks, etc. Other municipalities pick-up all trash and leave it up to the crane operator to pick out undesirable refuse.

2.3.6 Grates

The purpose of the grate system is to transport the refuse and residual ash through the combustion chamber. The grates are designed to allow the passage of underfire air from underneath the grates up through the grates and fuel bed. Certain grate designs (rocking grates and reciprocating grates) provide a significant amount of agitation of the refuse as it tumbles from one grate section to the next. Such agitation helps promote complete combustion. Traveling grates provide less agitation and are used primarily for RDF. In the United States, most stoker fired MWC's utilize reciprocating, rocking, or traveling grates.

Regardless of which of the three grate types are employed, the grates can be qualitatively divided into three sections. The first section is referred to as the drying or charging grate. Most of the drying in this section is a result of radiant heat from the furnace arches and walls. The second section is referred to as the ignition grates. The refuse is ignited in this section and a significant amount (approximately 50 percent) of the burning takes place in this section. The third and final section is referred to as the burnout or combustion grates. Combustion is completed in this section. The remaining residue (bottom ash and non-combustibles) falls off the end of the burnout grate, is quenched, and conveyed out for final disposal. (Ash handling is discussed in Section 2.4.) If a rotary kiln is employed, it normally is preceded by drying and ignition grates of the reciprocating type. The kiln serves the same purpose as the burnout grates.

From an operating point of view, the main concern about grates is preventing mechanical and thermal damage to the grate system. Mechanical problems include damage caused by allowing excessively heavy items to get into the furnace. Engine blocks, automobile transmissions and even refrigerators have been known to find their way into MWC's. As such heavy items tumble through the furnace they can bend, break, or otherwise severely damage the grates, sometimes requiring the plant to shutdown. Smaller material such as chains, wire, small pipes, etc. fall through the grate system and if not cleaned out periodically can jam the grates, requiring a shutdown.

Excess heat can warp or buckle the grates and the support system underneath the grates. This problem can be caused by high furnace temperatures or, probably more commonly, by excessive torching.

2.3.7 Slagging

Excessive furnace temperatures can cause slagging. Slagging occurs when temperatures in the furnace (or some portion thereof) are sufficient to fuse the ash. This causes the ash to run and to evaporate, but it will solidify or condense at the first opportunity. Different types of refuse produce different types of slag that have different melting and running temperatures. Slagging creates havoc with the grate systems by filling underfire air slots, thus creating poor air distribution. Slag can also interfere with the movement of the grates themselves. If the grates become completely frozen due to solidified slag, an immediate shutdown is required.

Slag formation on the furnace walls will cause premature deterioration of the refractory. Many MWC operators monitor for slag formation by regularly observing the appearance of the furnace refractory in the lower portion of the furnace. Fused ash sticking to the furnace refractory gives the walls a wet or glassy appearance.

2.4 ASH HANDLING

Many MWC operators report that the ash handling equipment creates more O & M problems on a day in - day out basis than any other system in the facility. As discussed below, some of these O & M problems result in air pollution compliance difficulties.

2.4.1 Ash and Residue Composition

If the residue produced by MWCs contained only bottom ash and fly ash the problem of ash handling would be much simpler than it is. Unfortunately, however, the residue contains a substantial fraction of non-combustible material, including glass fragments, metal material (cans, wire, axles, springs, sheet metal, motors, etc.), clinkers, rocks, and unburned organic material. This collection of variously sized material is abrasive and difficult to handle. Ash can be acidic or basic, depending on its source.

2.4.2 Ash Collection Points

The number and location of ash collection points will vary somewhat among MWC's, even if the facilities are of rather similar design. The following five collection points are common to many facilities in the United States.

1. Grates - Siftings are the ash and residue that fall through and are collected underneath the grates.

2. Quench Pit - The quench pit collects the bottom ash that falls off the end of the combustion grate. The quench pit contains water so that the ash is cooled for further handling.

3. Mixing Chamber - The mixing chamber holds the volatile furnace gases at the proper temperature long enough to allow complete combustion to occur. Heavy flyash falls out of the gas stream at this point. In some designs, this fallout is collected in the quench pit, i.e., the mixing chamber is directly above the quench pit. If the mixing chamber is slightly downstream of the quench pit, it is necessary to collect the ash at the bottom of the mixing chamber and evacuate the ash through a rotary air lock valve.

4. Cooling Tower - Cooling towers lower the temperature of the furnace exhaust gases via evaporative cooling prior to the gases entry into the air pollution device. The cooling towers often function as ash collection points because the tower vessel also acts as a gravity collector. To a limited extent, they also perform as prescrubbers. Sometimes cooling towers are referred to as quench towers or chambers, and if they precede a wet scrubber they may be referred to as a presaturator, if saturation of the gas stream is their function. Most MWC's with heat recovery do not utilize cooling towers.

5. Air Pollution Control Equipment - Electrostatic precipitators (ESP's), baghouses and scrubbers, of course, collect the fly ash produced by MWC's.

Rectangular batch furnaces typically have ash collection and storage hoppers directly underneath the grates. Periodically, ash and residue are removed, quenched, and accumulated in a residue hopper. Discharge from the residue hopper normally is done through a watertight gate valve into trucks or other containers and shipped to a disposal area, usually a landfill.

2.4.3 Ash Conveying Systems and O & M Considerations

The means of moving the ash and residue produced at MWC facilities can be broadly classified as either manual or continuous, with some plants using a combination of these techniques. This section focuses on ash handling problems that will adversely effect atmospheric emissions.

Quench Pit - Continuous ash removal operations employ a variety of means to move ash through the plant. The bottom ash moving off the grates is usually dumped into a quench pit. The water in the pit actually provides an airtight seal for the furnace. If the water level in the pit is not maintained at the proper level, the seal is broken and it becomes impossible to maintain proper furnace pressure and draft. A drag conveyor, submerged at its lower end in the quench pit, pulls ash from the pit to a holding hopper or in some cases directly into trucks for transport to a landfill. Since the drag conveyor is inclined, it allows some of the entrained quench water to drain back to the quench pit. Often, these drag conveyors become hung up with the odd sized material that accumulates in the quench pit. If these hang-ups occur above the water line they can usually (but not always) be cleared in a short time without interrupting operation of the furnace. If they occur below the waterline, it is usually necessary to drain the quench pit to gain access to the problem source. Draining the pit will break the airseal and result in higher emissions until the problem is corrected.

Grates - Siftings are removed from under the grates by vibrating or screw type conveyors, or by water sluices. The collected material is sent to the quench pit. Most facilities will observe the siftings conveyors area on an hourly basis to ensure that excessive amounts of material are not catching on beams and the grate drive system or jamming the conveyors. Sometimes such problems can be resolved by opening inspection doors and knocking the material off with long poles. This draws a lot of cold air into the furnace and thus usually creates an opacity problem. If solving the problem requires shutting down the furnace, even greater air emissions result.

ESP Hoppers - Fly ash from ESP or baghouse hoppers may be dumped through an airlock valve directly to a sluicing system, or it may be moved by a screw conveyor system prior to being dropped into a quench pit. Condensation in the hopper area can cause bridging of the ash, and can even cause the ash to create clinkers that adhere to the hopper walls. When the ash backs up into the ESP's electrical field it causes excessive sparking and eventually the ESP will short out. Most commonly, bridging and clinkering are caused by air in-leakage (ESP's are operated under negative pressure) in or near the hopper area. Cool ambient air leaking into the hopper condenses water vapor and acid gases. Another cause is excessive cooling at the cooling tower, or cooling tower spray nozzles that have deteriorated to the extent that they produce large droplets that cannot completely evaporate prior to entering the ESP. Yet another potential cause is leaking boiler tubes in MWC's equipped with heat recovery.

Sometimes the subsequent bridging can be rodded out while the MWC is in operation. If this fails, it is necessary to shutdown the facilitly to gain internal access to the hoppers.

Some operators report that bridging is sometimes caused by sticky material such as plastic film reaching the hoppers without being burned. This may be indicative of excessive airflows, especially underfire air, in the furnace.

Prevention of hopper problems entails aggressive maintenance procedures. The ESP's, hoppers and air lock valves need to be inspected for leaks at every opportunity. The air lock valves should be externally inspected and lubricated weekly when the MWC is in service.

From a design perspective, ash bridging and flow problems can be minimized through the installation of vibrators on the hoppers. Condensation can be minimized by insulating the hoppers or installing hopper heaters.

Mixing Chamber - The rotary air lock valve should be inspected for leakage internally at each opportunity and inspected and lubricated weekly when the MWC is in operation.

Summary - Basically, the important components of the ash handling system should be monitored frequently to ensure that residue is not backing up and thus creating a potential shutdown condition. These observations include checking water levels, flow rates, pumps, motors for rotary valves, and free movement of conveyors and residue.

The details of specific systems will vary from the description above. For example, facilities that recycle process water may send sluice residue directly to a clarifier, rather than to the quench pit. Also, recycle systems sometimes control pH of the process water by use of chemical additives. Regardless of the details of the methods and equipment employed at a given facility, clean and efficient operation of the MWC is tied directly to the reliable operation of the ash handling system.

2.5 AIR POLLUTION CONTROL EQUIPMENT

This section discusses the control devices encountered during the site visits: electrostatic precipitators (ESP's) and high energy wet scrubbers. The discussion is limited to the specific concerns brought to our attention by MWC operators. Regardless of the type of control device, a common concern expressed was corrosion control in the control equipment and ductwork. (Broader, in-depth discussions of control equipment design, O & M, and inspection, recordkeeping, and performance evaluation are discussed in the literature. For examples, refer to References 2, 3, 4, 5, 6, 7 and 8.)

2.5.1 Electrostatic Precipitators

ESP's are the most common particulate matter control device applied to MWC's today. This section will briefly discuss corrosion problems and useful monitoring and recordkeeping techniques for ESP's.

2.5.1.1 Corrosion: Causes and Prevention

A successful corrosion prevention program must first recognize that, as a result of the combustion reaction, MWC exhaust gases contain a significant water content. Also, water is added to the exhaust gases at many facilities either by design or accident. The acid content (mostly HCl) of the furnace exhaust gases further complicate the problem.

The effect of excess moisture on the ESP's ash hoppers was discussed in Section 2.4. The corrosion problem discussed here manifests itself primarily as ESP plate corrision. Within a very few years holes of several feet in area can develop. This requires municipal authorities to decide whether to engage in costly repairs or limp along with reduced plate area. Indeed, some MWC operators have expressed the opinion that a major ESP rebuild is required within seven years for units in MWC service. As operating experience has accumulated over the years, however, it becomes apparent that corrosion in MWC ESP's can be controlled to levels similar to those in other industries where rebuilding of the unit is not necessary for at least 15 to 20 years.

Cooling Tower - The purpose of the cooling tower is to lower the temperature of the exhaust gases to a point where the ESP will not suffer thermal damage. (Plate warping and buckling are the most common heat related problem. In more severe temperature excursions, the ESP's structural members can also be damaged.) The cooling is accomplished by evaporating a fine mist introduced into the gas stream by water sprays in the cooling tower. If too much water is introduced into the gas stream, all of the water cannot evaporate before entering the ESP, thus creating a potential corrosion problem.

If the spray nozzles in the cooling tower have eroded substantially, they may produce a course spray (large droplets) that cannot completely evaporate prior to entering the ESP. Again, moisture in the ESP chamber establishes a corrosion hazard.

A thermocouple is placed near the entrance to an ESP. The signal is sent to the control panel so that the MWC operator can monitor the inlet temperature. The signal is also sent to a controller that governs the quantity of water supplied to the cooling tower. It is imperative that the operator monitor this system so that he can take appropriate action if the performance of the cooling tower deteriorates for any reason. The cooling tower spray nozzles and the thermocouple should be inspected at every scheduled outage for MWC's that operate for at least a month continuously.

Air In-Leakage - Since ESP's operate under negative pressure any leakage through cracks or pinholes on the enclosure will allow air to move from the outside to the inside. Cool air coming into the unit is likely to cause condensation of moisture and acid gases. If plate corrosion is confined to a limited area, air in-leakage should be suspected since airflow in the ESP is not turbulent; air streams from holes and cracks tend to maintain their integrity, do not diffuse very much, and thus tend to attack rather small areas.

The insidious characteristic of air in-leakage, however, is that it tends to feed on itself. If an air stream from a leak flows in a manner that causes it to contact the shell of the ESP, the ensuing condensation will cause corrosion at that location, ultimately creating another route for leakage. Another common source of leaks are deteriorating seals on access doors.

The ESP should be thoroughly inspected for leaks at least on a quarterly basis if the operating schedule allows it. It is important to correct any problems found during the inspection before the system is brought back on-line. Otherwise, the situation will likely be much more severe at the next shutdown.

As unlikely as it may seem, it is advisable to inspect a new ESP prior to the initial startup to ensure that the field erection crews have welded all appropriate seams in the ESP shell and hopper areas. MWC and other ESP operators have learned this technique through the school of hard knocks.

Shutdown - Every time an MWC is shutdown, the hot, water vapor laden exhaust gases in the ductwork and ESP must cool to below the dewpoint. In effect, the ducts and air pollution control device take an acid bath every time the system is shutdown. Obviously, the corrosion this process inevitably causes is more severe if shutdowns are frequent. Facilities that regularly shutdown on a weekly schedule probably have the most severe problem.

Two steps can be taken to alleviate condensation during shutdowns. The first is to minimize the number of unscheduled shutdowns by implementing an aggressive O & M plan, particularly on those parts of the system whose failure can cause a shutdown situation, e.g., the ash handling equipment, the grate drives, and the air pollution control system itself.

Second, if the normal operating schedule calls for a weekly shutdown, it is then feasible to install an ESP heater. An ESP heater is basically an oil or gas burner installed in the duct on the inlet side of the ESP. The heater is fired up for short term (weekend) shutdowns, preventing the exhaust gases in the ESP from condensing during the shutdown period.

Performance Monitoring - Virtually all MWC operators who employ ESP's do some performance monitoring. The commonly monitored electrical data include primary current, primary voltage, secondary current, secondary voltage, and spark rate. Many older units do not monitor secondary voltage and some of the newer systems do not include a spark rate guage. Regardless of the details as to precisely what data is available for a given unit, most operators record the electrical data on an hourly or bi-hourly schedule. Table 2-2 is a typical log for recording the secondary electrical data.

The ESP electrical data is a powerful tool for evaluating the overall performance of the unit and in diagnosing performance problems. The reader is referred to the EPA publication in Reference 2 for an excellent discussion of the utility of these parameters.

Another useful parameter for evaluating ESP performance is opacity. Federal New Source Performance Standards (NSPS) do not require continuous monitoring of opacity at MWC's. Indeed, some MWC's normally operate with condensation occurring downstream of the control device, making continuous opacity monitoring unfeasible. Yet many other units do not create such steam plumes. Thus, many states have incorporated continuous opacity monitoring permit requirements on a case by case basis. Where opacity data is available it can be very useful in evaluating performance and diagnosing problems. Again, Reference 2 provides an excellent discussion on how to utilize opacity data as a diagnostic tool.

2.5.2 Wet Scrubbers

High efficiency scrubbers for MWC's include variable and fixed throat venturi scrubbers and flooded disc type venturi scrubbers. One of the major problems with wet scrubber performance as applied to MWC's is control of the condensible, partially oxidized organic matter which forms when incinerator operating temperatures are too low. The organic material condenses while passing through the scrubber, creating an aerosol with a particle size too small for effective impaction in the scrubber. Few scrubbers have been able to achieve the NSPS emission limits because of this problem (Reference 3).

Corrosion is a major concern in wet scrubber operations, as it is with ESP's. For scrubbers, the solution is centered around control of the scrubber's liquor quality. The paragraphs below briefly discuss the impact of liquor quality on system performance.

TABLE 2-2

ELECTROSTATIC PRECIPITATOR LOG

Incinerator No. _____
Date _____

	Field No. 1			Field No. 2		
	Secondary Voltage (KV)	Secondary Current (Ma)	Spark Rate (per min.)	Secondary Voltage (KV)	Secondary Current (Ma)	Spark Rate (per min.)
1 am						
2 am						
3 am						
4 am						
5 am						
6 am						
7 am						
8 am						
9 am						
10 am						
11 am						
Noon						
1 pm						
2 pm						
3 pm						
4 pm						
5 pm						
6 pm						
7 pm						
8 pm						
9 pm						
10 pm						
11 pm						
Midnight						

Liquor Quality, Corrosion, and Performance - From both a performance and maintenance perspective, liquor quality is critical to the scrubber's reliable operation. The critical parameters are pH, and suspended and dissolved solids. The rigor with which a source operator monitors these parameters may not need to be as severe for a scrubber utilizing a once through system, but most operations recycle a significant fraction of the spent liquor; some recycle all of it with fresh water introduced only to make up for evaporative losses. The concern for liquor quality applies to both the liquor supplied to any cooling tower or presaturator and to liquor supplied to the scrubber itself.

In municipal incinerators, scrubber liquor tends to become acidic due to the absorption of HCl and organic acids in the liquor. Acidic conditions can quickly lead to serious corrosion problems everyplace downstream of where the acid liquor is introduced. Thus, the spray chamber, ducts, scrubber, entrainment separator, ID fan and stack can suffer corrosion problems. In areas of the system that are under positive pressure, (i.e., the scrubber is preceded by the ID fan) the holes and cracks from corrosion in the system will allow untreated combustion gases to escape to the environment. For those portions of the system under negative pressure, holes and cracks in the system can substantially reduce the ID fan's ability to control draft in the furnace. In addition, in-leakage of ambient air causes localized condensation of moisture and acid gases, the resulting liquid exacerbating the corrosion problem. Thus, you have something similar to a monster feeding on itself.

Liquor pH and water make-up rate can be monitored and controlled automatically at the clarifier just before the recycled liquor is reintroduced to the system. The pH of the liquor should be maintained above the levels at which carbon steel is attacked. A pH of 6 or greater is usually satisfactory. Chemicals utilized to reduce pH are usually sodium hydroxide, ammonia, or lime.

The dissolved and suspended solids content of recycled liquor varies from source to source, but can be as high as 15% by weight. Since a major portion of the liquor injected into the quench tower and/or presaturator evaporates, some of the solids entering as suspended and dissolved solids in the liquor are released as particulate matter (Reference 11). High solids content also is often responsible for excessive erosion of pipes and pumps, and pluggage of spray nozzles.

Samples of the liquor should be analyzed periodically, even if this requires sending the samples to an outside laboratory. High solids content in the liquor can be eleviated by several methods including more frequent blowdown of the scrubber liquid system and a lower recycle rate.

Proper control of other scrubber variables such as pressure drop and liquid-to-gas ratio are also critical to maximizing scrubber performance. For a more detailed discussion of these parameters, the reader is referred to Reference 3.

2.6 FANS, DUCTS, AND STACKS

As auxilliary systems the importance of fans, ducts and stacks to the overall operation and performance of an MWC is easy to underestimate. This section briefly describes some of the salient O & M concerns for these auxilliary systems.

2.6.1 Fans

Operation and maintenance considerations for fans depend on several factors. These factors include the type of service (and locations) the fan is in, fan size, fan type, and whether the fan is a direct drive or belt driven unit. Regardless of any general "rules of thumb" provided here or elsewhere, source operators should follow the specific fan manufacturer's recommendations for the nature and frequency of fan maintenance procedures as minimum requirements for reliable fan performance.

The fans of principle concern at municipal incinerators are the combustion air fans (underfire, overfire, and if applicable, sidewall cooling fans) and the induced draft (ID) fan. Generally, the combustion air fans are constant speed devices with airflow controlled by dampers. The ID fans may also be constant speed units, but variable speed units are probably more common.

Most ID fans are located between the air pollution control system and the stack. If the ID fan precedes the air pollution control equipment, problems related to abrasion, erosion, corrosion, and build-up of solids on the fan will be more severe. The only "solution" to this is frequent inspection and cleaning.

ID fans serving scrubber systems operate under substantially more severe conditions than those serving dry systems. This is due to the humid conditions that enhance the possibility of condensation of acids on the fan and fan housing. Even if the ID fan preceeds the scrubber, the fan is usually placed after the cooling tower, since the cost of a fan that can handle the substantially higher gas volumes and temperatures that occur upstream of the cooling tower would be prohibitive.

Regardless of its location, the ID fan is usually equipped with water cooled bearings and a vibration sensor that will sound an alarm in the plant and illuminate emergency lights in the control room if vibration becomes excessive. In some

systems, the sensor controls will automatically shutdown the fan and open an emergency stack in preparation for an emergency shutdown. Aside from the fact that the furnace cannot operate properly without the ID fan, everyone working around industrial fans should be aware that vibration is a preliminary indication that the fan might shake apart at anytime, possibly throwing fan parts considerable distances at substantial risk to life and property.

Fan current for all fans is often monitored in the control room. At a minimum, this information tells the incinerator operator whether fans are operating or not and can provide rough estimates of airflows. These meters may also include audible alarms or emergency lights that indicate no current. If the ID fan loses current, many systems will, again, automatically begin shutdown procedures.

Table 2-3 illustrates a typical fan inspection and preventative maintenance schedule. Operating experience or the manufacturer's recommendations may dictate a more frequent inspection and maintenance than indicated here.

2.6.2 Ducts

Air ducts are a passive part of the incinerator system. Nevertheless, proper maintenance of the ducts is critical to the overall performance of the system. Two problem areas are addressed in this section, leakage and deposition.

Leakage - Leaks in air ducts result from any of several causes, including corrosion, abrasion/erosion, flex failure and failure of expansion joints. Leaks can occur as holes, cracks, and fissures in the duct system. The causes and effects of such leakage will vary somewhat, depending on whether they occur in ducts that are under positive or negative pressure.

Positive pressure ducts occur downstream of the ID fan. In most systems, this is only a small fraction of the total duct system. A few incineration systems however, locate the ID fan upstream of the air pollution control device, thus creating substantial duct lengths between the fan and control device and continuing on to the stack. In a positive pressure environment, leaks occur from the duct to the ambient atmosphere. Between the fan and the control device, this means that untreated furnace gases are exhausted directly to the atmosphere.

Air in-leakage occurs in negative pressure ducts. Negative pressure ducts occur upstream of the ID fan. In most systems, the ID fan is the last unit operation prior to the stack, so most of the ductwork, in fact, most of the entire system, including the furnace, the air pollution control device and cooling towers, operate under negative pressure.

TABLE 2-3

TYPICAL FAN INSPECTION AND PREVENTATIVE MAINTENANCE SCHEDULE

INSPECTION/MAINTENANCE ITEM	DAILY	WEEKLY	MONTHLY	SEMI-ANNUAL
Vibration Check	X			
Oil Level		X		
Oil Color		X		
Oil Temperature		X		
Lubricate		X		
Bearings Check				
Noise	X			
Leaks			X	
Cracks			X	
Loose Fittings			X	
Inspection (Internal) (Clearances, Wear, Pitting, Scaring)				X
Clean and Inspect Blades and Internal Housing				X[1]
Fan Belt				
Noise Check	X			
Belt Tension and Wear	Whenever the fan is out of service			

[1]Fans in scrubber service may require cleaning on a monthly or quarterly schedule.

Air in-leakage creates several problems. The first is that it tends to feed on itself. Leakage of cold ambient air into the ducts encourages localized condensation of acidic vapors that tends to create more holes and cracks. As this situation propagates, the ID fan attempts to pull more and more air. It becomes difficult for the furnace operator to maintain the proper furnace pressure and draft.

Ducts should be inspected externally for leaks on a monthly basis, more often if the facility has a history of leaky ductwork. Small leaks are difficult to locate by an external inspection. Internal inspections performed during daylight hours have the advantage of highlighting small holes and cracks due to contrast between the dark duct interior and bright daylight. Internal inspections should be performed on a quarterly schedule.

Particle Deposition - Dust build-up is an inevitable difficulty in many horizontal duct sections upstream of the air pollution control device due to the impractical economics of maintaining air velocities that are sufficient to carry the very largest particles in the gas stream. Consequently, many designers provide conveniently located clean out ports so that the build-up can be easily removed. Excessive build-up in MWC systems result from oversized ductwork, or, more commonly, excessive underfire air and/or furnace draft that tends to carry significant quantities of unburned material out of the furnace and into the air handling system.

The consequences of excessive dust build-up are several. First, by reducing the cross-sectioned area of the duct, build-up increases air velocity. This consequence alone can deteriorate the performance of the air pollution control device. Second, by moving the entire air stream over to one portion of the duct, maldistribution problems in ESP's are likely to occur, despite turning vanes and gas distribution plates, which were never designed to correct for excessive dust build-up. Finally, duct systems are not usually designed as load bearing structures. The build-up of excessive quantities of material in air ducts can (and sometimes does) lead to collapse of the duct support system or the duct itself. Aside from requiring an immediate shutdown and rather expensive repair, collapse of ductwork is potentially dangerous to plant workers.

2.6.3 Stacks

Stacks are another passive system from an operational procedures perspective. Air pollution agencies are concerned about only a few specific aspects of the initial design. First, of course, is the stack height. The function of stacks is to lift incinerator effluents to a suitable elevation above ground level so that the air pollutants remaining in the effluent can be adequately dispersed and diluted prior to being returned to ground level. Second, if the stack is to be the sight of stack sampling ports and/or pollutant monitoring instruments (transmissometers, SO_2 gas analyzers, carbon dioxide monitors, etc.) then the design must provide for safe access to the ports and instruments, including appropriate scaffolding.

Twenty or more years ago it was common for municipal incinerators to operate without air pollution control equipment. In those days, MWC's operated by natural draft, rather than with ID fans. The installation of air pollution control equipment required cooling the incinerator effluent to provide temperatures in a range that would not damage scrubbers, baghouses, or ESP's. A second important aspect of the gas cooling was the reduction in gas volume that followed. The cooler, slower gas stream now required an induced draft fan so that the incinerator operator could maintain proper furnace draft and pressure. The complications this created for stack design relates to the increased potential for condensation of acid containing vapors on the stack liner. Most incinerator operators schedule a thorough stack inspection on a yearly basis. The inspection addresses both the structural integrity of the stack and chemical attack of the liner. Often these inspections are conducted by outside firms who specialize in stack maintenance.

Observation of the physical stack can sometimes assist in identifying or diagnosing problems elsewhere in the incinerator system. Stacks in scrubber service, for example, sometimes develop a mud lip, that is, the stack exit becomes covered with wet particulate matter. This is generally the result of a malfunctioning entrainment separator.

Some operators have been known to cut "windows" in the stack near the base. The purpose for doing this has never been clear. Aspirating ambient air into the stack lowers the stack gas temperature, thus increasing problems related to condensation of acids in the stack. In addition, the lower gas temperatures decrease plume bouyancy, thus decreasing the effective stack height and resulting dispersion at ground level. Finally, in most jurisdictions, dilution of the stack gases in this manner is considered a circumvention of the opacity emissions limitation.

2.7 STARTUP AND SHUTDOWN

Startup and shutdown are routine activities at MWC's that can cause periods of excess emissions. The excess emission problem is much more severe for startup than it is for shutdown. This section describes operating procedures that can minimize excess emissions during startup and shutdown.

2.7.1 Startup

It is common for newer MWC's to use auxiliary burners as a means of achieving a prescribed minimum furnace temperature before waste is charged to the system. However, for MWC's which do not utilize auxiliary burners, the typical startup is a procedure in which the refuse loading and the combustion air are gradually increased, and during which time the furnace temperatures are intentionally controlled below the levels required for optimum combustion. The initial charging rate normally varies from one-third to one-half of the design rate and is increased stepwise over the duration of the startup period.

During startup, particulate matter and opacity emissions can be extremely high. This is due to the low furnace temperatures that exist for the first two to four hours. The result is incomplete combustion and the generation of large quantities of soot. The reason for the long startup interval is the necessity to slowly heat the MWC refractory material and downstream components and thereby prevent damage from rapid expansion. Rapid temperature increases can result in spalling and premature failure of the refractory and similar heat stress problems for the grate system. For units equipped with boilers, all of the pressure parts of the boiler must be heated and gently expanded into their position at full operation. Typically, the rate of temperature increase at the boiler outlet is limited to 100°F increase per hour as a uniform gradation in temperature, i.e., a 25°F increase in boiler outlet temperature every 15 minutes. Since the boiler outlet temperature at full load operation conditions is approximately 650°F, this would result in a startup period of approximately 6 hours. Excessive opacity will be generated for the first 2 to 4 hours. On the more sophisticated MWC systems, it is possible to reduce the startup time somewhat by bypassing the economizer or air preheater at the tail end of the boiler so that the flue gas temperature is increased as rapidly as possible to the air pollution control equipment.

Electrostatic Precipitators - During the initial 4 hours of startup, the flue gas products going to an ESP can be wet and sticky due to low flue gas temperatures. If the ESP is placed in operation at the time the furnace is ignited,

it can be difficult to remove the sticky particles from the plates. As the flue gas temperature increases these particles can bake onto the plate. This situation can reduce the efficiency of the ESP when the MWC is fully charged. This is why many manufacturers of electrostatic precipitators do not recommend power be turned on until the acid dew point temperature has been exceeded at the ESP outlet. If the MWC is equipped with ESP heaters as described in Section 2.5, the heater can be used to preheat the ESP prior to furnace charging, thus allowing the control device to be energized much earlier in the startup process.

Economizers - In order to exceed dew point temperature in the control equipment as quickly as possible, a bypass of the water around the economizer is required so that the economizer will not reduce the flue gas temperature during startup. Most economizers are equipped with bypass piping so that the feedwater can be bypassed and not permitted to pass through the economizer. This can decrease the time necessary to achieve an adequate flue gas temperature by as much as 2 hours. The problem with this procedure occurs in putting the economizer into service once the boiler has been brought up to pressure and placed on line. At this time the economizer will generate steam when feedwater is introduced into it and this steam must be vented out through the vent valve at its top until the steambound economizer can begin to circulate water to the boiler without being injurious to the boiler. This requires a high degree of operating skill on the part of the plant personnel.

Air Heaters - Air heaters can also be bypassed. This requires a duct between the discharge of the forced draft fan and the windbox area of the stoker. This prevents the forced draft air from being preheated by the flue gases, therefore allowing a more rapid increase of the flue gas temperature at the air pollution control equipment.

Multiple Furnace Facilities - An effective way to eliminate opacity problems during startup at multiple furnace facilities is to provide interconnections among the various furnaces and the air pollution control equipment. With such a setup, the air pollution control equipment (ESP or baghouse) associated with a boiler coming on line can be preheated to a point above the acid dew point temperature by a slip stream(s) from the flue gas of other fully operating furnaces. Thus, baghouses and ESPs can be brought on-line much earlier in the startup process. Maintenance of damper seals is very important in an interconnected setup so that the potential for air infiltration and out-leakage is eliminated.

Superheaters - During startup of a unit, the superheater section and reheater sections could be flooded with feedwater if hydrostatic testing has been conducted. If so, the refuse feed rate into the furnace must be held low enough to allow the water that was in the superheater (or reheater section) to be converted to steam and vented to the atmosphere. During the initial startup of the boiler, thermocouples are normally attached to determine the time it takes to boil away all of the water in each and every superheater or reheater element. The refuse feed rate must be limited to ensure that the superheater and reheater elements are heated and cleared slowly so that saturated steam may pass through them and not cause overheating of superheater metal. This time/temperature curve is drawn up by the boiler manufacturer for each and every boiler at initial startup. Time must be allowed, especially at the very low firing rates where excessive opacities can be generated, to clear these units. After clearing the liquid water from the superheater, heating the superheater metal is usually limited to 50°F per hour. Thus, clearing liquid water and gentle heating of the superheater usually requires about ten hours. After this ten hour period, the stack gas is hot enough to allow energizing the ESP or bringing the baghouse on-line.

Short-term Shutdowns - The MWC startup time can also be greatly reduced if the MWC is to be shut down for a short time over a weekend, by converting the MWC and air pollution equipment into a "thermos bottle". This requires (1) the complete stoppage of the forced draft fan air flowing through the furnace after the MWC has been brought off line and steam is no longer being generated in the unit and (2) not allowing any air leakage into the setting and not allowing natural stack effect of the high temperature flue gases (i.e., gases at 300°F or 400°F should not be allowed to pass through the MWC to heat the tailend economizer, air heater, or ID fan, and then pass out the stack). By making a "thermos bottle", the MWC will minimize the loss of heat and fast startup (3 to 4 hours) can be accomplished. When startup is initiated the following Monday morning, the internal MWC temperature is already up to 250°F to 300°F instead of the ambient air temperature of 70°F to 80°F.

Most operators do not make the effort to stop the natural draft through the MWC, thereby cooling the furnace and increasing the length of time for system startup. It is most desirable to prevent a MWC system from cooling down if the unit is to be off line for a short period of one to three days. Such cooling is undesirable because it takes more time to startup a cold furnace. Also, a furnace that is allowed to cool down from operating temperature to ambient air

temperatures (e.g. 70°-80°F) requires more maintenance than a unit that cools to only 250°-300°F. The greater and more frequent the expansion and contraction of the pressure parts and refractories, the more maintenance that will be required.

2.7.2 Shutdown

The shutdown of an MWC does not generally cause significantly increased emissions. Charging is discontinued, but grate movement, airflow, and operation of the air pollution control system continue as appropriate until all the refuse in the furnace has been burned. Heat retained by the refractory and other interior parts keeps temperatures at acceptable levels for the 1 to 2 hours required to completely burn out the refuse after charging has been discontinued.

2.8 EQUIPMENT INSPECTION FREQUENCY

Clean, efficient MWC operation requires an aggressive preventive maintenance program. Such a program includes getting out of the control room or office to periodically inspect, evaluate and repair equipment.

Table 2-4 presents an example of a schedule for inspection of incinerator equipment by the incinerator staff. It must be understood that, as an example, the inspection frequency tabulated here should not be interpreted as the only acceptable frequency to ensure reliable operation of the system. For example, many of the hourly and daily inspection checks itemized here may be inverted at a specific facility or may be performed on a "once per shift" basis. Similarly, in some facilities the monthly and semi-annual inspections may be performed on a quarterly basis, especially if the facility routinely shuts down on a quarterly basis and the nature of the inspection requires internal access to the furnace, ductwork, control equipment, etc.

The inspection schedule implies a certain amount of routine maintenance must be performed as needed. For example, if an hourly check of the conveyors indicates a jam, obviously it must be corrected immediately. The fact that different inspection frequencies are recommended for specific pieces of equipment implies that inspections of different levels of detail are required. For example, the cooling tower exit temperature is the only means to measure the performance of the cooling water sprays on an hourly basis. However, many plants will check the spray pumps for excessive bearing noise on a per shift basis, and lubricate the bearings on a weekly basis. Stand-by pumps are often run through their transfer cycle on a weekly basis. The spray nozzles are usually inspected (and cleaned or replaced as needed) during every scheduled shutdown.

TABLE 2-4

EXAMPLE INCINERATOR

EQUIPMENT INSPECTION FREQUENCIES

Equipment	Hourly	Daily	Weekly Lube & Inspect	Monthly	Semi-Annual	Bi-Annual
Cranes		x	x	x	x	x
Feed Hoppers		x	x	x		
Grates		x	x		x	
Air Box					x	
Conveyors	x	x	x			
Refractory						x
Fans			See Table 2-3			
Rotary Kiln	x	x	x		x	
Diversion Gate	x	x	x			
Dump Trucks		x	x	x	x	
Rotary Valve Air Locks		x	x			
Cooling Water Sprays	x		x	x		
Cooling Chamber	x			x		
By-Pass Stack		x		x		
ESP			x	x	x	
Stack					x	
Controls & Sensors		x		x		
Quench Pit Water Level	x					

Differences in technology, design detail and operating experience ultimately dictate required inspection and maintenance frequencies for specific incinerator components. More can be inferred about system reliability from whether or not a facility has a written inspection and maintenance schedule that they adhere to than can be inferred from the details of such a schedule.

2.9 RECORDKEEPING

Management and technical personnel at MWC facilities require certain information about the plant's operation so that they can monitor the efficiency, production and reliability of the operation and take corrective action when necessary. This information includes data about throughput, operating parameters for the furnace, combustion, and air pollution control processes. Fortunately, efficient and reliable MWC operation is totally consistent with good air pollution practice. Therefore, the records and reports maintained by the MWC staff are normally more than adequate to satisfy recordkeeping and reporting requirements that may be desirable as stipulations in air pollution permits. An exception, excess emission reporting, is discussed later in this chapter.

2.9.1 Furnace and Combustion Data

Section 3.3 contains an example furnace and combustion data log. Such logs are maintained by the furnace operator. Typically, these logs are manually compiled with readings recorded hourly or bi-hourly. However, there is a clear trend on newer installations to compile this data on computer with current and historical data available to the operator via CRT and/or paper.

Precisely what data is available and recorded at a given facility will depend on the basic MWC configuration, the sophistication of the automatic combustion control system and the experience/opinions of the MWC management.

Monitoring the instruments is essential to maintaining a clean, efficient operation and preventing minor process excursions from becoming substantial and costly equipment problems and environmental compliance difficulties. Creating a historical record of the process operation provides MWC management with a tool to evaluate trends in process operation and malfunctions.

2.9.2 Stack Gas Monitoring and Excess Emission Reporting

Figure 2-1 is an illustration of a typical Continuous Monitor Quarterly Report. These reports can be rather laborious for plant staff to prepare if there is

FIGURE 2-1

Page _____ of _____

Bureau of Air Quality Control

CONTINUOUS MONITOR QUARTERLY REPORT

_____ Calendar Quarter 19 _____

SIP ___ NSPS ___ (Check one)

Source Name _____ Address _____
City State Zip

Emission Point _____

Check Appropriate Boxes:

☐ This report is for incidents of excess opacity (reported in % opacity), opacity monitor downtime or repair. Duration is reported in minutes.

☐ This report is for indicated excessive gaseous emissions (SO_2 & NO_x reported in lbs./10^6 BTU), monitor downtime or repair (including CO_2, O_2 monitors).

☐ There have been no recorded incidents of excess opacity or gaseous emissions and the monitoring system has not been inoperative.

Incident No.	Date	Start Time (AM or PM)	% Opacity or lbs/10^6 BTU	GAS MONITOR (Check One) SO_2	NO_x	CO_2	O_2	Duration (Mins.)	NATURE AND CAUSE OF INCIDENT	CORRECTIVE ACTION

Name and title of person responsible for data: _____
Signature Title Date Submitted

a large quantity of excess opacity excursions during the quarter. If the facility is maintaining continuous compliance adequately, the reports can be compiled in a very few minutes. It is the former case that presents a compelling argument for permit conditions that require the preparation and submittal of such reports.

In addition to documenting the time, duration, and severity (percent opacity) the report requires the identification of the nature and cause of the incident and the corrective action taken. These last two data columns provide the most important information in the report. Most often, those facilities that experience difficulty in achieving continuous compliance do so because they have one or two operating problems that create the bulk of the violations (Reference 12). If the data are summarized to indicate which problems are causing the most violations, the plant management and, if necessary, the state or local air pollution control agency, can focus on the solution to the problem.

To date, EER's have not been required at MWC's utilizing transmissometers. In view of the wealth of useful information that can be derived from EER's, it is desirable to re-evaluate this approach.

2.9.3 Miscellaneous Records

Additional recordkeeping at MWC facilities will vary widely from plant to plant and, in general, will be of marginal use to air pollution authorities. It is helpful, however, to be aware of the broader recordkeeping activities since some facilities will have useful environmental data tucked away on a record that otherwise may seem rather obscure.

Figures 2-2 and 2-3 illustrate two forms utilized by the Montgomery County (Ohio) Solid Waste Management Division in operating two MWC's at each of two sites in the County. Figure 2-2 is the Incinerator Shift Operations Record filled out at the end of each shift by the Shift Foreman. The record provides summary information for the shift regarding operating time and throughput (grapples fed and loads of residue hauled). Ammonia is used to control pH of the process water, so the amount of ammonia used and the pH at each clarifier is recorded once per shift at this facility. The ESP is equipped with an oil heater that is fired during brief shutdowns to prevent acid condensation. Thus, the amount of diesel fuel used per shift is also recorded.

Figure 2-3 is the Combustion Condition Observation Form. This form is used as part of the Division's training program and is used on a random basis to document operating observations. The value of the form is to encourage operators to make appropriate observations of the combustion conditions and, just as important, make appropriate corrections or explain why not.

FIGURE 2-2

INCINERATOR SHIFT OPERATIONS RECORD

Plant_____ Date_____

Shift No.	Operating Hours From	Operating Hours To	Downtime Hours From	Downtime Hours To	Grapples Fed	Loads of Residue Hauled
Furnace 1						
Furnace 2						
_____ Shift Foreman	Truck#___ Gals___ Truck#___ Gals___		Diesel___ Gals___ PH #1___ PH #2___		Ammonia Reading___ Amount Used_____	

Remarks: _____

DATE _____

FIGURE 2-3

COMBUSTION CONDITION OBSERVATION FORM

	Extremely Dry			Very Wet	
Condition of Refuse	_____	_____	_____	_____	_____
	Poor Burnout			Good Burnout	
Condition of Ash #1	_____	_____	_____	_____	_____
Condition of Ash #2	_____	_____	_____	_____	_____
	Dirty			Clear	
Condition of Plume	_____	_____	_____	_____	_____

Drafts: All Balanced & Approximately Correct: _____ yes _____ no

If not, Explain: _____

Grate & Kiln Speeds: All Balanced & Appropriate Conditions: ____ yes ____ no

If not, Explain: _____

Combustion Air Fans: All running, quiet and clean intake: ____ yes ____ no

If not, Explain: _____

Combustion Air Seals: All doors shut, rotary locks working, and ash quench filled with water: _____ yes _____ no.

If not, Explain: _____

_____
Division Chief Engineer

Response of Operator:

_____

Signatures:

_____	_____	_____
Incinerator Operator In Charge	Shift Supervisor	Chief Operation Supervisor

_____ _____
Comments Plant Manager

(Forward to Superintendent After Reviewed & Signed by All.)

2.9.4 Charts and Computers

Many facilities continuously record furnace and cooling tower temperatures and opacity on strip or circular charts. Even in such cases the operators are usually required by management to manually log these parameters.

The extent to which computers are used at MWC's varies greatly from plant to plant. Any automatic combustion control system is a computer, if somewhat rudimentary by today's standards. Some facilities also utilize the computer as a data recorder and logger. Operating parameters such as furnace temperatures and oxygen concentration can be monitored via a CRT. In addition to the instantaneous values, the computer is usually programmed to provide historical summaries and hourly averages of the operating parameters. Precisely what data are routinely printed will, again, vary from plant to plant. Facilities involved with steam production usually have the most sophisticated control systems.

2.9.5 Summary

MWC facilities utilize rather extensive recordkeeping practices to operate and control the combustion process and the movement of municipal waste and combustion residue through the plant. These records are also useful to the plant staff in diagnosing and resolving operational problems, whether those problems result in excess air pollution emissions or not. The air pollution control official will generally not need records beyond those maintained at responsible MWC operations. He should be aware of the normal (baseline) operating ranges of critical parameters such as furnace temperature, oxygen concentration, ESP secondary power levels, and scrubber pressure drop that are specific for the facilities in his jurisdiction. He should also be aware that operation outside the baseline ranges for these critical parameters is an indication of a potential air pollution problem.

Transmissometers have proven successful in a number of MWC applications. Facilities should be encouraged to install and maintain transmissometers that meet the 40 CFR 60 Appendix B specifications in any new or existing facility where water vapor in the stack or duct is not a problem, and, in the case of existing units, where the remaining useful life of the unit can justify the expense. It must not be forgotten, however, that the opacity data generated by such instruments is totally useless if it is simply stored in a box at the plant or the air agency's offices.

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CHAPTER 3

SITE VISITS AND OPERATING VARIABLES STUDY

3.1 INTRODUCTION

This chapter discusses several operating and air pollution compliance problems described by MWC operators during the MWC site visits performed under this study. Each "case history" describes the nature of the problem or concern faced by the operator and the action or solution implemented to resolve the issue. The kinds of problems addressed in the case histories are fairly typical in the MWC industry. Thus, it is hoped that these presentations may be useful to other MWC operators.

Also discussed in this chapter are the results of a field study conducted at the Stamford, Connecticut MWC. The purpose of this field study was to determine the relationship of operating variables routinely monitored at the facility to opacity emissions.

3.2 SITE VISITS - CASE HISTORIES

Case History No. 1 - This facility operates two mass burn rectangular batch furnaces rated at 100 tons per day each. The two cell furnaces are equipped with rocking grates. The furnace exhaust gases are treated by a single two field electrostatic precipitator. The facility operates on a five day per week schedule.

The ESP was installed in 1980 as part of a refurbishing and upgrading program for the overall system. The operating staff and engineering contractor were aware of the corrosion difficulties ESP's suffer in MWC service. Further, the facility's five day per week operating schedule was expected to exacerbate the corrosion potential since each shutdown would cool gases in the ESP to below the acid dewpoint.

To eliminate this problem, an oil heater was installed in the inlet duct of the ESP. The heater is fired during weekend shutdowns to prevent acid condensation. The oil burner consumes 200 to 300 gallons of fuel oil during the weekend to maintain ESP internal temperatures around 275°F. Often it is not necessary to fire the burner in the summer.

The ESP's are inspected internally once per month. Corrosion has been negligible over the seven years of operation. The facility superintendent feels that the cost of the fuel oil is insignificant compared to the benefits derived from the

burner. However, in view of current fuel oil costs, he would recommend a burner that utilizes natural gas.

Case History No. 2 - This facility was experiencing fugitive dust problems resulting from tipping floors that were not fully enclosed and unpaved roadways on the plant premises. In 1982 the tipping areas were completely enclosed with sheet metal siding and large overhead garage doors. Further, a program to install asphalt paving on unpaved roads was initiated in 1981 and completed within three years. These newly paved roads are swept regularly with automatic road sweeping equipment. This program has brought the facility into compliance with local fugitive dust control requirements and has resulted in a substantial reduction in citizen complaints.

Case History No. 3 - Exhaust gases from four rotary kilns are treated by each of four venturi (cone-type) scrubbers. The scrubber liquor is a 100 percent recycle: make-up is for evaporative losses only. Liquor treatment is provided by a clarifier/still well system. No provision is made for pH control.

The system was suffering from persistant and advanced corrosion in the scrubbers, mist eliminators, ducts, and ID fan housing. Observations at the site of stack gas emissions confirms opacity measurements varying from 20 percent to 80 percent during normal operations. Furthermore, little difference in the plume appearance could be noted with and without the venturi scrubbers in service. This suggests a plume comprised predominately of submicron particles that are not removed by the scrubber. Such particles are typical of the soot and cracked hydrocarbon tars which characterize opacity due to incomplete combustion.

At the time of the site visit, the MWC management had installed an ammonia system to control the pH of the scrubbing liquor. In addition, they had begun a program to refurbish each of the four furnaces and control systems one at a time. The refurbishment of the first system was near completion at the time of the visit. The project had included rebuilding the ducts, scrubber and mist eliminator to replace corroded parts and repair holes and cracks as necessary. Additional water capacity was added to the presaturator. To improve combustion conditions, overfire air was added to the furnace.

Case History No. 4 - The ESP ash hoppers at this MWC were suffering frequent bridging problems. The original installation of the system did not include vibrators on the hoppers to aid ash removal. Installation of vibrators solved the problem.

Case Ilistory No. 5 - This facility consists of two rotary kiln MWC's. As is typical with such systems, the kiln is preceded by a furnace equipped with drying and ignition grates and combustion air supplied by overfire and underfire nozzles. Air pollution control is achieved by two ESP's with three fields each that vent into a common stack. The ESP's were installed in 1982, replacing a wet scrubbing system.

During the first year of operation the ESP's experienced re-entrainment problems when the third fields were rapped, causing opacity violations. The re-entrainment problem did not occur everytime the third fields were rapped, but appeared to occur only when poor combustion occurred in the furnace, specifically when the furnace was burning highly combustible waste. The resulting incomplete combustion produces fine, light particles of soot that the ESP's can collect, but due to the low resistivity of the particles, they become re-entrained during rapping.

To resolve the problem, the frequency of third field rapping was reduced to once every 24 to 48 hours and interconnect ducts were installed between each MWC line and ESP. This allows the exhaust gases of both MWC's to be vented to one ESP while the third field on the idle ESP is rapped. With no airflow in the idle ESP, no opacity violations can occur during rapping.

After installation of the interconnect system, opacity violations were reduced to 1.67 percent of the total operating time. Almost half of the remaining violations were related to startup of the facility. Yet, the larger half still appeared to be related to some kind of uncontrolled combustion caused by a specific waste. By coordination of various members of the operating staff the problem was isolated and identified as a highly combustible waste from a styrofoam processing plant. Apparently, the resistivity/re-entrainment problem related to this waste was so severe, the ESP's simply could not handle it, even with the interconnect procedure. The firm was contacted and informed that the MWC facility could no longer accept the firm's waste.

Case History No. 6 - In 1983 this facility shutdown two furnaces to perform an extensive rebuilding of the ESP's serving the furnaces. The rebuilds were necessary because of extensive corrosion in the ESP's, particularly in the outboard plates where holes of several square feet in area had developed. Prior to the rebuilding effort the ESP's had operated reliably for almost nine years. The facility superintendent felt that this is good performance for ESP's in MWC service. Nevertheless, the superintendent is taking precautions to ensure that the MWC system is operated in a manner consistent with long term reliability of the rebuilt

unit. This includes maintaining furnace exit temperatures and ESP inlet temperatures as high as possible to minimize the chance of condensation and carryover of cooling tower spray in the ESP. For these units, maximum furnace exit temperatures are 1600°-1650°F. Temperatures over 1700°F tend to cause slagging. The ESP maximum inlet temperature is set at 650°F. The units have also had some difficulty with welds breaking in the hopper assembly, allowing air to leak in. These breaks are repaired during scheduled downtime.

Case History No. 7 - This facility consists of two RDF fired traveling grate stokers with tail end boilers. Emissions are controlled by ESP's. Local air pollution officials had documented several opacity violations and had received complaints about ash fallout in the neighborhood.

Although the combustion air for this system is controlled automatically, the feed rate, as dictated by the speed of the screw conveyor, was controlled manually. The MWC staff developed software to provide automatic control of the feed rate based on the steam demand. Automatic feed control eliminated quenching the bed by feeding too much fuel. To gain further control of the excess air rate, the staff repaired cracks in the furnace system to minimize air in-leakage. The combination of these measures eliminated the opacity and ash fallout problems.

Additional system refinements are planned for the future. First, the operators are planning to install oxygen and carbon monoxide monitors. This installation is part of a long term plan to provide combustion control through these parameters rather than furnace temperature, which is the current practice. The operators also believe they can provide better combustion control by eliminating the fly ash reinjection system. Finally, the ESP's pneumatic rappers will be replaced by hammer rappers. It is believed that the pneumatic rappers do not provide sufficient energy to properly clean the plates.

Case History No. 8 - Two ESP's control particulate matter emissions from two travelling grate RDF fired furnaces. Auxiliary fuel is used during startup and when flame out occurs on the fuel bed. Originally No. 6 oil was the auxiliary fuel. The oil created opacity violations (the standard is 20 percent) and citizen's complaints were registered. These problems were eliminated by switching to natural gas.

Another problem at this site has been clinker formation in the ESP ash hoppers. The clinker causes the ash to bridge, thus backing the ash up into the ESP itself. When the ash approaches the plates the electric field is disrupted, causing

the ESP to short out. The MWC staff has investigated the problem and they are convinced that the bridging is not caused by air in-leakage/condensation. At the time of our visit they were considering rebuilding the hoppers so that the hopper walls are almost vertical and the openings to the ash conveyors below are substantially larger than the 8-inch diameter valves currently in service.

The fuel delivery system (air blast distributors) has suffered some abrasion problems in the ducts where the RDF is blown onto the traveling grate. The abrasion apparently is caused by glass contained in the RDF. (Refuse processing at this facility does not include an air classification system that would eliminate glass from the fuel. Basically, the fuel processing at this facility entails hand sorting, magnetic separation, and shredding by a hammermill.) Although the problem has not been completely eliminated, some improvement was noted when a local bottle bill went into effect. Returnable glass bottles resulted in less glass in the RDF and also resulted in a small but noticeable increase in the heat content per unit mass of the RDF.

3.3 OPERATING VARIABLES VS. OPACITY STUDY

In an effort to determine how MWC operating practices affect visible emissions, a field study was initiated in the City of Stamford, Connecticut at their co-disposal (municipal solid waste and sewage sludge) incineration facility. The purpose of the study was to attempt to correlate "real world" operating data routinely compiled by the MWC staff to the visible emissions emitted by the facility. The operating parameters such as furnace temperature, underfire air pressure, furnace pressure, etc. recorded hourly over ninety days were statistically correlated to the hourly opacity readings from the opacity monitor.

The 360 ton per day (tpd) Stamford MWC was chosen because the facility met several selection criteria established by the EPA. Specifically,

1. The facility has a good overall visible emission compliance record and is in generally good mechanical condition. Therefore, it was known that good operating practices can produce good results at this facility.

2. The Stamford staff has conducted several studies on combustion efficiency and throughput and thus has experience in data collection and analysis.

3. Except for the co-firing of sewage sludge, the equipment configuration at Stamford is reasonably typical of intermediate to large size MWC's currently in operation in the United States.

4. The Stamford facility has an opacity monitor.

5. An east coast location for the test facility was necessary for economical travel for EPA Headquarters and contractor staff.

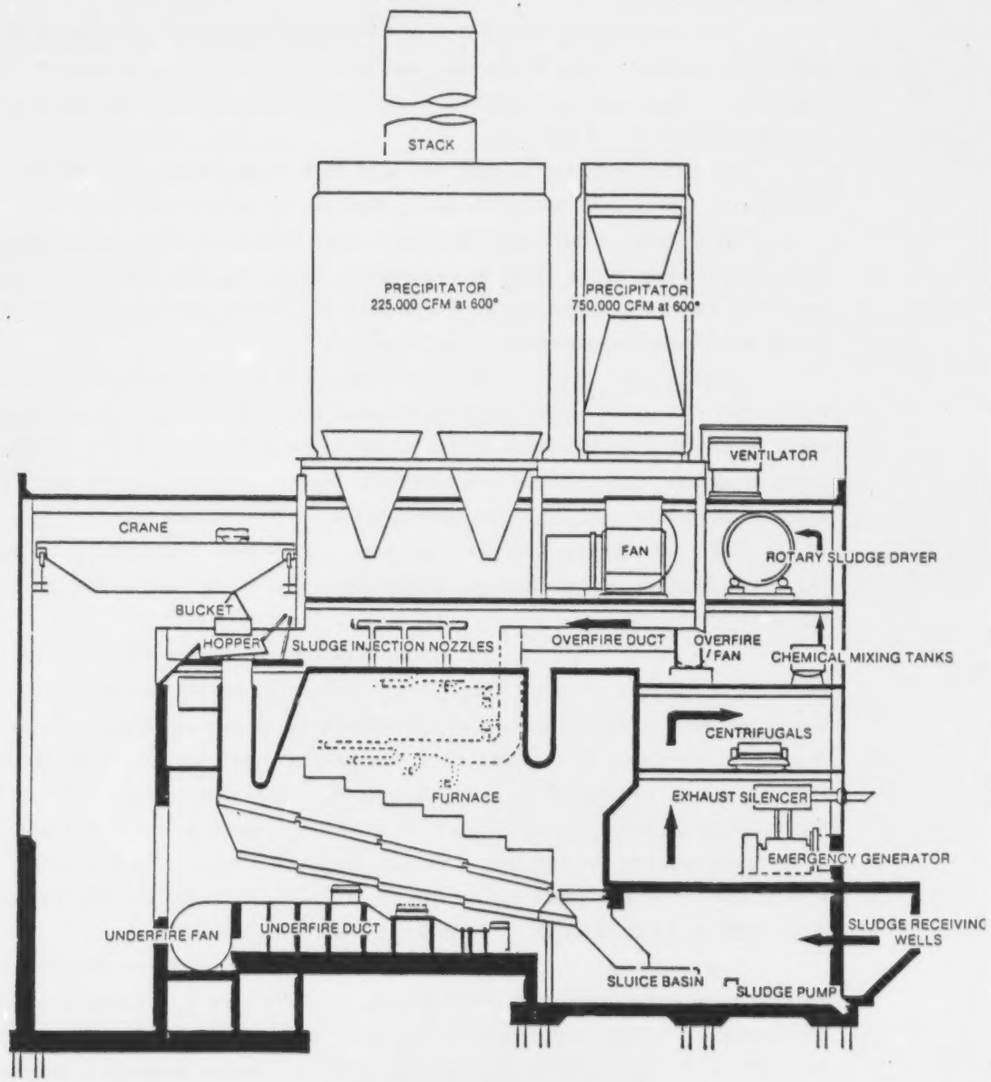
This section provides a process description of the Stamford 360 tpd MWC. This is followed by a description of the field study protocol. Finally, a brief discussion of the results and conclusions are presented.

3.3.1 Process Description

The 360 tpd MWC in all ways, except one, is a "typical" mass-burn unit with continuous feed of unprocessed municipal waste, rocking grates, and an ESP to treat exhaust gases. The one exception to this unit being typical is the use of energy to process the solids removed from the sewage treatment plant. The MWC is designed to process 30 tons per day of dried sewage sludge with a maximum moisture content of 20 percent from belt filter presses. The sludge comes from the city's 20 million gallon per day (mgd) wastewater treatment plant located on the same site. Sludge processing is accomplished by two belt filter presses, a rotary kiln that uses a slip stream from the furnace exhaust to dry the sludge, and the MWC. The dried sludge is fed to the MWC continuously from the kiln through several openings in the furnace ceiling. Figure 3-1 is a schematic of the Stamford waste processing facility. Flyash laden water from the process water system is pumped to a separator/clarifier that is part of the MWC. The city also operates a 150 ton per day batch MWC at this site that is not a part of this study.

Waste Handling and Storage - Trucks dump refuse into a receiving bin that has a capacity of 425 tons level full and 725 tons heaped. This design capacity is based on the assumption of a refuse density of 12.4 pounds per cubic foot. (More typically, refuse density is 25 lbs/ft^3 which means that the receiving bin capacity may hold twice the design capacity). The refuse consists of residential, commercial, and industrial waste. Other types of waste such as pathological or hazardous wastes are not processed at this faciliity. The proximate analysis of the municipal refuse burned is typically 55 percent combustibles, 30 percent moisture, 15 percent ash and has a heat content of approximately 5400 Btu/lb. The furnace feed hopper is served by two air conditioned cab cranes each with a 2-cubic yard grapple. The hopper delivers refuse to a refractory lined continuous feed chute connected to the furnace. Refuse in the chute provides an air-tight seal for the furnace when in operation. A hydraulically powered cover seals off the hopper during shutdown periods.

Figure 3-1
Schematic of Stamford Incinerator



Source: Reference 1

The receiving bin is equipped with water sprays that are designed primarily for fire suppression. When sensors in the bin roof detect abnormally high temperatures, alarm annunciators in the control room signal for manual operation of the spray nozzles.

Three sludge wells are located in the building in addition to sludge pumps, belt filter presses, drying equipment, and chemical conditioning storage/mixing facilities. With a maximum moisture content of 20 percent, the sludge burns at a maximum hourly rate of 1.25 tons.

Hot gases from the furnace are used in a sludge drying heat exchanger (rotary kiln) with heat exchange exhaust ducted back to the combustion chamber.

Dried sludge is introduced into the furnace through openings in the furnace roof, with burning taking place in suspension prior to reaching the furnace bed. Typically, the dried sludge fed to the furnace will have a heating value of 3000 Btu/lb and a moisture content less than 10 percent.

Furnace and Grates - The combustion chamber is of wet-bottom design; i.e., a pool of water is maintained in the bottom into which bottom ash and larger particles in the exhaust stream settle out and are removed in a slurry. A water make-up system automatically maintains the desired water level with manually operated dump valves provided for the draining of the flyash laden slurry.

The lower furnace walls are subjected to abrasion from moving refuse. Thus, this portion of the furnace is outfitted with air cooled silicon carbide refractory materials.

Waste is agitated and transported through the furnace by a series of rocking grates on which the refuse burns. Rocking grates are arranged in rows across the width of the furnace, at right angles to the solid waste flow. Alternate rows are mechanically pivoted or rocked to produce an upward and forward motion, thus advancing and agitating the solid waste. The rocking grate stoker is hydraulically driven. The same hydraulic system also operates the refuse hopper cover and a chute at the high end of the ash drag-out conveyor. The furnace grate area is 355 ft^2 with a grate loading of approximately 80 $lb/hr/ft^2$. The furnace dimensions are 12 ft. in width, 39 ft. in length, and 29 ft. in height.

Combustion Air - Combustion air is provided by underfire air, sidewall cooling, and overfire air forced draft systems. Underfire air is that portion of the combustion air which is introduced to the chamber from beneath the grates. The underfire air is manifolded to several areas under the grates, where it is directed upward so that the air passes through the grates and refuse.

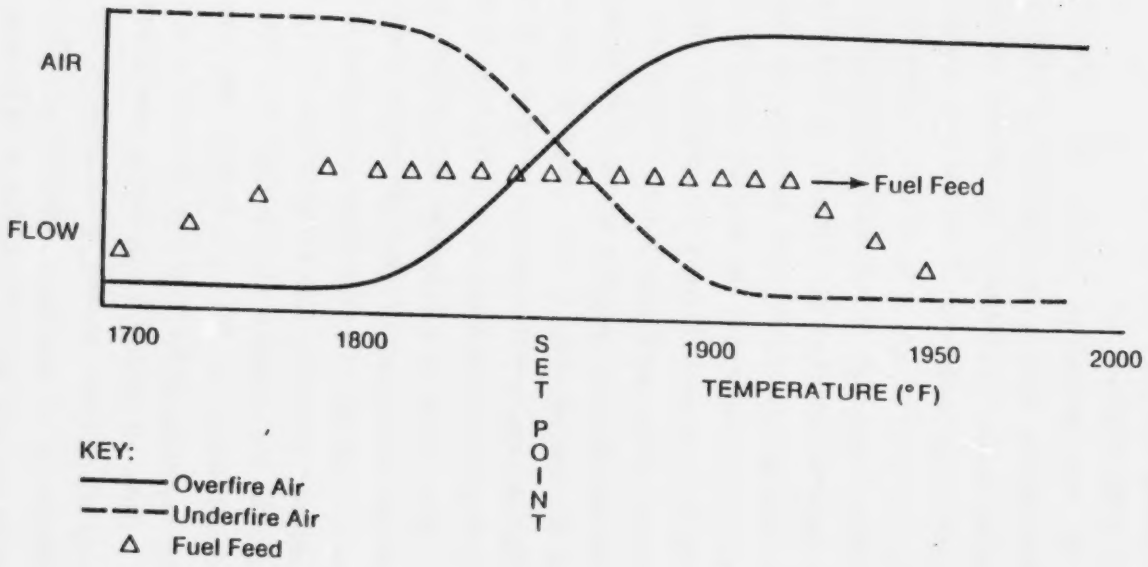
The underfire air is furnished by a 70,000 cfm fan that is modulated by an inlet damper. The underfire air fans are designed to provide sufficient velocity (energy) to the underfire air jets so that the combustion air penetrates the fuel bed, thus providing maximum contact of combustion air with the solid, combustible material in the refuse.

In the automatic mode, the volume of air delivered by the underfire/overfire system is regulated through a control system driven by a temperature sensor located near the furnace ceiling. The control system increases the volume of underfire air if the furnace temperature is too low simultaneously reducing the overfire air. The volume of underfire air is decreased if the furnace temperature is too high, simultaneously increasing the overfire air. The movement of the underfire/overfire air dampers is always proportional, i.e., they move in opposite and approximately equal amounts. By viewing Figure 3-2 one can see the position that the underfire and overfire are at in respect to each other both inside and outside the selected burning temperature. The amount of air being delivered to the furnace by the overfire air system is monitored by a draft gauge on the overfire air duct just after the overfire air fans, the amount delivered by the underfire air system is monitored by a draft gauge on the underfire air duct just after the underfire air fans, and the total air movement through the incinerator is monitored by a draft gauge on the outlet side of the forced draft fan.

Two 12,500 cfm fans with inlet damper controls supply overfire air. The reasons for introducing overfire air are to ensure, through added turbulence, the complete oxidation of combustible gases that have evolved from the solid refuse fuel bed, and to control high temperatures in the furnace. (As described above, an increase in the overfire airflow quenches the furnace gases.) Overfire air is introduced above the fuel bed through the furnace sidewalls. The overfire air system was designed for complete penetration of the exhaust gases.

Sidewall cooling is supplied by two 15,000 cfm fans. Although the primary purpose of sidewall cooling is to protect the refractory, sidewall cooling air contributes to the overfire combustion air. The sidewall cooling air fan damper is manually operated and normally set at 40 percent open.

Figure 3-2
Conceptual Relationship Between Underfire/Overfire/Temperature



Air Pollution Control - The emission control system consists of a spray chamber followed by an ESP. The water spray chamber reduces the combustion gas temperature to between 550° and 650°F prior to entering the ESP. The spray chamber consists of a multiple bank spray system, with cluster type nozzles providing 100 micron diameter droplets at 125 psi. Spray volume is automatically controlled in 45 to 50 gpm increments. The spray chamber has high-heat heavy duty fireclay brick walls with a castable refractory similar to that of the combustion chamber.

The ESP is located on the roof because of site restrictions. The ESP consists of two electrical fields and is designed to handle 225,000 acfm at 600°F and a maximum pressure drop of 0.5 inches water column. Motorized dampers on the inlet duct control flow under abnormal operating conditions. The cross-sectional area of the ESP was designed to provide a velocity of 3 to 4 feet per second through the unit in order to allow adequate detention time and limit dust re-entrainment. ESP design parameters are summarized in Table 3-1. An induced draft (ID) fan is downstream from the ESP. The fan has a radial tip blade, a variable speed drive unit, and is sized for 202 bhp.

Inlet dust loading conditions are 3.5 pounds of particulate matter per 1000 pounds of dry gas, adjusted to 50 percent excess air for product of combustion. Maximum particulate matter concentration in the ESP discharge is 0.175 pound per 1000 pounds of dry gas was specified; equivalent to 95 percent efficiency. Sampling ports are installed on the inlet and outlet ducts of the ESP for performance testing. Sampling ports are also available on the exhaust stack.

Multiple hoppers at the bottom of the ESP collect flyash, with rotary valves for removal. Slide gates have been installed upstream of these valves to facilitate maintenance without emptying the hoppers. From the rotary valves, the collected flyash drops into a sluicing system and is conveyed by suspension in water to the ash drag-out conveyor trough.

The ash handling system consists of stationary packers receiving the residue from the ash drag-out conveyor. The residue is then transferred into ash receiving containers and hauled to disposal sites.

TABLE 3-1

ESP PARAMETERS

Equipment Parameter	Value
Control Efficiency (Design)	95% minimum
Plates	18 gauge cold rolled mild steel
No. of Fields	2
Wires	Weighted Wire Design
Plate Area	39,000 sq ft
Distance from wire to plate	4.5 in
Rappers	Solenoid (Replaced later with pneumatic rappers)
Hoppers	60° hopper slope, electric heaters and vibrators. Discharge valves: rotary feeders
Instrumentation	Analog meters for primary and secondary current and voltage for each field. Spark meter on inlet field only.

Flue Gas Parameters	Value
Air Volume (design)	225,000 acfm at 600°F
Gas Velocity	3.0 ft/sec minimum 4.0 ft/sec maximum
Inlet Temperature	550°F - 650°F
Maximum Temperature	700°F
Exhaust Gas Moisture	1500 lb/min
Inlet Particulate Loading	3.5 lb/1000 lb[1]
Outlet Particulate Loading	0.175 lb/1000 lb[1]

[1]Pounds particulate per 1,000 pounds dry gas @ 50% excess air.

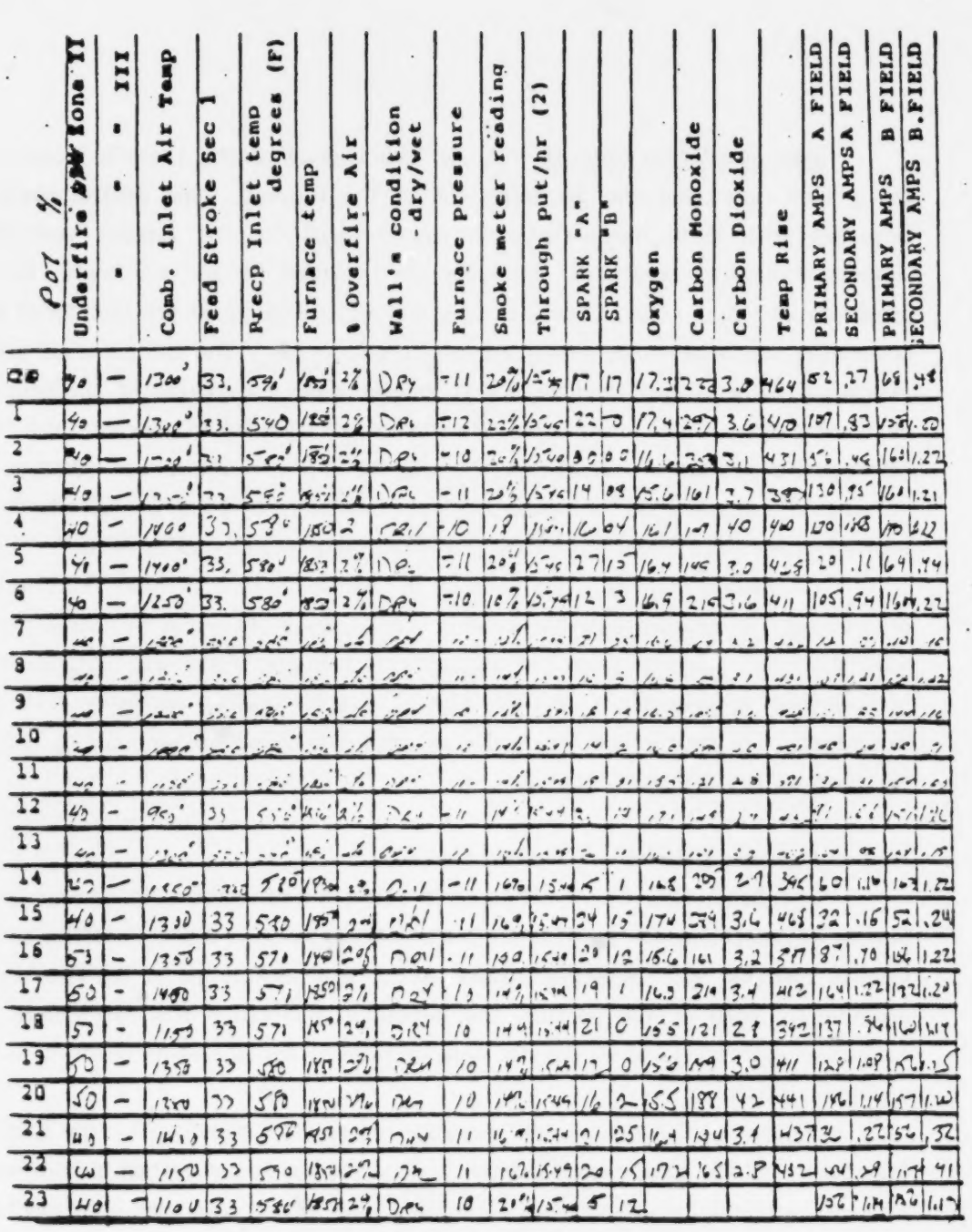
Instrumentation Controls - An air-conditioned control room is located on the ground floor near the discharge end of the furnace. The control room is furnished with basic instrumentation and controls for the furnace and ESP. Automatic controls and panel readouts are provided for air and water supply pressures and flow rates. Fans, pumps, and control dampers are monitored and controlled manually when not in the automatic mode. The temperature probe measuring furnace exit temperature is located near the center of the primary chamber ceiling. All the temperature probes are shielded to prevent false high readings attributable to radiant energy within the combustion chamber. Continuous gas sampling and analysis for smoke density is conducted by a self contained system located on the third floor. Operating procedures require daily calibration.

An opacity monitor is installed on the exhaust stack. A chart recorder for data storage is included with the opacity monitoring system and is located in the control room. Records were not available to indicate if the unit has passed a performance specifications test or when the last relative accuracy test was conducted. The instrument zero and span drift is checked and adjusted daily by a certified instrumentation technician.

3.3.2 Field Study Protocol

The field study was a cooperative effort between the City of Stamford's Bureau of Sanitation and the U.S. Environmental Protection Agency's Office of Air Quality Planning and Standards. After review and acceptance of the field study protocol by each of the parties, the Bureau of Sanitation was responsible for collecting approximately 60 days of data on process and operating conditions, and visible emissions.

Figure 3-3 illustrates the operating parameters provided by the City of Stamford. All the data except oxygen, carbon monoxide and carbon dioxide were part of the original study concept. The gas concentration data were coincidentally being collected by the MWC staff as part of a preliminary program to look at certain conditions to assess the feasibility of: 1) if and what should be replaced of the antiquated nitrogen dioxide, oxygen, carbon monoxide and carbon dioxide monitoring equipment supplied with the facility in 1973; and 2) the possible addition into the overfire/underfire/temperature control loop of feed with trim control within span provided by the carbon monoxide concentration. To minimize expenses for the preliminary program, the Sanitation Department borrowed a $CO/CO_2/O_2$



Pot #	Underfire Zone II	" " III	Comb. Inlet Air Temp	Feed Stroke Sec I	Precp Inlet temp degrees (F)	Furnace temp	% Overfire Air	Wall's condition -dry/wet	Furnace pressure	Smoke meter reading	Through put/hr (2)	SPARK "A"	SPARK "B"	Oxygen	Carbon Monoxide	Carbon Dioxide	Temp Rise	PRIMARY AMPS A FIELD	SECONDARY AMPS A FIELD	PRIMARY AMPS B FIELD	SECONDARY AMPS B.FIELD
00	40	—	1200°	33.	540°	1850°	2%	DRY	-11	20%	1250	17	17	17.2	222	3.0	464	82	.27	66	.48
1	40	—	1300°	33.	540	1850	2%	DRY	-12	22%	1250	22	10	17.4	297	3.6	470	107	.82	1250	.55
2	40	—	1200°	33	540°	1850	2½%	DRY	-10	20%	1250	8	10	16.6	333	3.11	431	96	.46	160	1.22
3	40	—	1200°	33	540°	1850°	2%	DRY	-11	20%	1250	14	08	15.6	161	2.7	348	130	.95	160	1.21
4	40	—	1400	33.	580°	1850	2	DRY	-10	18	1300	16	04	16.1	149	40	440	120	.68	170	1.22
5	40	—	1400°	33.	580°	1850	2%	DRY	-11	20%	1250	27	15	16.4	146	3.0	425	20	.11	64	.44
6	40	—	1250°	33.	580°	1850	2%	DRY	-10	18%	1250	12	3	16.5	216	3.16	411	1050	.94	1650	.22
7	[illegible]	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	[illegible]	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	[illegible]	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	[illegible]	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	40	—	[illegible]	33	[illegible]	[illegible]	[illegible]	[illegible]	-11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13	[illegible]	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14	[illegible]	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-11	1600	[illegible]	[illegible]	1	16.8	205	2.7	346	60	1.14	1650	1.22
15	40	—	1350	33	540	1850	[illegible]	[illegible]	-11	[illegible]	[illegible]	24	15	17.4	224	3.6	468	32	.16	52	.24
16	50	—	1350	33	570	1850	[illegible]	[illegible]	-11	1600	[illegible]	20	12	16.6	161	3.2	377	87	1.70	136	1.22
17	50	-	1400	33	571	1850	[illegible]	[illegible]	-13	[illegible]	[illegible]	19	1	16.3	214	3.4	412	164	1.22	1320	1.20
18	50	-	1150	33	571	1850	[illegible]	[illegible]	-10	[illegible]	[illegible]	21	0	[illegible]	121	2.8	342	137	.84	1340	[illegible]
19	50	—	1350	33	550	[illegible]	[illegible]	[illegible]	-10	[illegible]	[illegible]	17	0	[illegible]	[illegible]	3.0	411	1280	1.09	[illegible]	[illegible]
20	50	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-10	[illegible]	[illegible]	16	2	[illegible]	188	4.2	441	186	1.14	1570	[illegible]
21	40	-	[illegible]	33	[illegible]	[illegible]	[illegible]	[illegible]	-11	[illegible]	[illegible]	21	25	[illegible]	[illegible]	3.1	[illegible]	[illegible]	1.22	1560	[illegible]
22	40	—	1150	33	570	[illegible]	[illegible]	[illegible]	-11	[illegible]	[illegible]	20	15	[illegible]	[illegible]	2.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
23	40	—	1100	33	580°	[illegible]	2%	DRY	-10	20%	[illegible]	5	12					1250	[illegible]	[illegible]	[illegible]

Figure 3-3. Sample Data Sheet for Stamford Incinerator

FORMULA

1) Feed stroke = add strokes/section x 12 + sec delay time ÷ feed section setting

2) $\left(30.67 \times \left(\frac{60 \times 60 \times 1}{\text{feed stroke}}\right)\right) \div 27 \times 250$ = lbs per hour

lbs per hour ÷ 2000 = tons per hour

3) Average throughput = throughput/hr ÷ number of throughput/hr reading during shift

instrument that was designed to compute combustion efficiency for oil, gas or coal combustion.

During the course of the study, it was desirable to manipulate some of the operating variables over specific ranges to broaden the data base. Specifically, it was agreed to attempt the following:

Furnace Temperature: During the course of the study, it was recommended that the furnace exit temperature be run from 1600°F to 1900°F and back to 1600°F in 50 degree increments. To ensure that the furnace stabilized at each temperature level, each increment was to be held for at least four hours. After considerable discussion with the Superintendent of Sanitation, Mr. Marvin Serra, and the Solid Waste Division Staff, it was decided that determination of upper and lower bounds through opacity violation would not be an acceptable means. Further it was determined that 1) variation of the temperature, because it affected throughput, could only be accomplished when time permitted, and 2) operating above 1900 degrees F could not be permitted because of possible high heat problems with the ESP.

Corona Power: The corona power would be adjusted through controlling the voltage. The run would be similar to that done for the furnace temperature. However, some experimentation was required to determine how low the power could be set without causing opacity violations. At the upper end, an excessive spark rate could be noted. Once the upper and lower limits were defined, the test would begin at the lower power setting and increased incrementally every four hours to the upper power limit and back to the lower limit.

Manipulation of other operating variables was considered but rejected as not being practical. For example, fly ash resistivity is dependent on flue gas temperature (among other things). The range of responsible ESP operating temperatures is not very large. The upper limit is defined by what the unit can take without suffering heat damage. The lower limit is defined by how much water can be injected at the cooling tower without carryover of liquid droplets into the ESP. Since this temperature range is limited, the fact that the temperature would not be controlled to better than plus or minus 10 to 20°F became significant to the overall temperature range available.

3.3.3 Discussion, Results, and Conclusions

The operating parameters were run through a multiple regression analysis to determine which parameters had a good correlation with opacity. It was anticipated that several parameters could provide a good correlation, indicating that monitoring and controlling certain process operating variables would produce acceptable emission levels.

Operating personnel were only partially successful in regulating furnace temperature and ESP corona power and thus determining their impact on stack opacity. The reason that the furnace temperature could not be easily regulated can be attributed to several factors. The two most significant factors are the broad range of refuse burned and the inability of the system to control the refuse through-put (the majority of the time it was required to be at maximum).

One of the methods most commonly used to analyze data is a simple linear regression and correlation, from which a correlation coefficient can be derived. The correlation coefficient is an index measure of the degree of linear association between dependent and independent variables. The linear regression equation is the straight line that best fits the data. The closer the correlation coefficient is to unity (1.00), the stronger the linear relationship is likely to be. Correspondingly, for inverse relationships, the strongest correlation coefficient would be -1.00.

Conclusions - The following conclusions were drawn from the analyses.

1. The statistical analyses that were performed emphasized opacity and carbon monoxide concentration in the exhaust gases as dependent variables, while other process parameters such as carbon dioxide concentration, oxygen concentration, furnace throughput, furnace temperature, ESP temperature, etc., were considered independent variables. The analysis involved determination of the arithmetic mean and standard deviation of the variables, the correlation coefficient to measure the strength of relationship between two variables, and a simple regression equation (which shows the best aggregate correlation between variables).
2. Statistical analysis of the available data was unable to establish any reliable correlation between stack opacity and any other independent variable.
3. Analysis of the data also showed no strong correlation between CO concentration and any variables such as furnace temperature (-0.12), carbon dioxide (-0.05), oxygen (0.14), refuse burn rate (0.07), ESP inlet temperature (0.05), or stack opacity (0.03). The low correlation coefficients among the gas concentrations may be the result of utilizing a gas monitoring instrument that was not designed for the use employed by this study.
4. All of the outputs (meters and strip charts) indicated that the variables were constantly varying at various rates. This is typical and expected for the operating variables at an MWC. Recording instantaneous readings at

the end of each hourly period may raise the question as to how representative the data may be of the actual operation for that hour. Ideally, the pluses and minuses associated with each reading would, over a 90 day period, cancel each other out. The correlation factors resulting from this analysis indicate strongly that 1) the sample population may not have been large enough, or 2) the high variability in refuse composition and operating conditions had a strong impact on the analytical results. If the latter is true, an automated data logger that can output hourly averages of the dependent and independent variables, rather than instantaneous readings at the end of each hour, may have produced higher correlation coefficients. However, installation of such a device would have violated the "real world" operating and recordkeeping criteria defined in the first paragraph of Section 3.3.

5. Another difficulty in analyzing MWC operating data is the lag time between cause and effect when adjusting one operating variable to improve the value of another. For example, if the combustion air is adjusted because the furnace temperature moves out of the acceptable range, the furnace temperature will not respond instantaneously, but only after some period of time - perhaps anywhere from several minutes to one-half hour, or so.

6. The opacity monitor was audited on July 24, 1985. The monitor is of a design common in the 1960's and early 1970's where an automobile spotlight is used as the light source, and an unfiltered selenium photocell is used as the detector. The monitor meets the requirements of the operating permit issued by the Connecticut Department of Environmental Protection. The U.S. EPA does not require opacity monitors at municipal incinerators. However, monitors of this design are not capable of meeting the U.S. EPA performance specifications contained in 40 CFR 60 Appendix B. However, the audit report (Appendix A) concluded that the unit's performance was adequate for the purpose of the Stamford pilot study. In addition to summarizing the audit results, the report provided recommendation for calibration and upgrading the system. The audit was originally scheduled to coincide with the start of the pilot study. However, due to process equipment replacement requirements for the study (ESP control system replacement which was completed before the data collection), and the replacement of the opacity monitor (which was not completed before the

data collection) the pilot study was delayed. Startup of the pilot program actually occurred on March 31, 1986.

3.4 REFERENCES

1. Gates, D.W., Incinerator is Part of Integrated Waste Disposal System, reprint from Public Works Magazine, May 1974.

APPENDIX A

AUDIT

OPACITY METER

STAMFORD MUNICIPAL INCINERATOR

AUDIT
OPACITY METER
STAMFORD MUNICIPAL INCINERATOR

BY

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JULY 26, 1985

EASTERN TECHNICAL ASSOCIATES
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VII. RECOMMENDATION FOR REPLACEMENT OF PRESENT SYSTEM

I. INTRODUCTION

Eastern Technical Associates was contracted to perform a survey audit of the transmissometer located on the municipal incinerator in Stamford, Ct. The purpose of this survey was to determine the suitability of the transmissometer in determining the effects on in-stack opacity by varying the operational parameters of this incinerator. The incinerator is a well maintained and operated unit equipped with an electrostatic precipitator. The unit has a history of operating within the emission limitations of the State and EPA. The transmissometer is on the incinerator stack for operational controls only. This source is not required to have an opacity meter. Thus the transmissometer is not required to meet the EPA specifications for a continuous emission monitor. The study of the effects of changes in incinerator and collector operational parameters on in-stack opacity does not require full compliance with EPA CEM specifications.

The management and staff of the municipal incinerator were extremely helpful in assisting in the conduct of this audit to the point of working overtime to assure our success. Their assistance and cooperation is sincerely appreciated.

II. TRANSMISSOMETER SYSTEM DESCRIPTION

A. GENERAL SYSTEM DESCRIPTION

The transmissometer system is very similar in design and operation to those used in smoke generators used for opacity training and certification in the late 60's and early 70's. It is a single pass unit consisting of a automobile Searchlight source, a selenium photocell and a stripchart recorder.

B. INSTALLATION

The transmissometer is installed on the stack just above the roof over the 4th floor of the incinerator building. The stack diameter at that point is approximately 10 feet. The stripchart recorder and control console is located remotely in the main incinerator control room.

C. SOURCE

The source is a 6.3 volt automobile spotlight that is controlled via a variac and stepdown transformer. This allows the adjustment of the light intensity to match the range of the photocell. As the light intensity goes down the beam becomes rich in infrared radiation and the system becomes insensitive to the smaller particles responsible for the scattering of light most visible by human observers. Thus this type system is almost never photopic and generally underestimates opacity. The type of light used has two distinct beam widths. There is a stronger inner beam and a wider weaker beam. This is not really suitable for a transmissometer.

D. DETECTOR

The detector is a selenium photocell probably manufactured by International Rectifier and repackaged. It is unfiltered and therefore not fully photopic in response. This type of cell can be linear if operated with an output of over 15 millivolts. At the time of the survey the sensitivity or output of the cell was attenuated to 20 millivolts with a 1 turn 20 K Ohms pot. The wiper of the pot was worn out and it was difficult to adjust and was not stable. With the assistance of the staff electrician we replaced the pot with a Burns 10 turn precision pot of equivalent resistance. This corrected the instability problem and made the adjustment of the output simpler.

E. RECORDER

The recorder appeared to be in good con'ition and responded to values across the scale. Due to the nature of the source and the detector the chart was difficult to read. The quick response time of the system can be reduced to alleviate this problem. The recorder is set up to report in Ringleman Numbers, from 0 to 5.

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III. AUDIT PROCEDURES

A. STANDARDIZATION

The normal standardization procedure (calibration) could not be performed. This was due to the fact that it is a single pass instrument and the incinerator could not be turned off. Instead we performed a relative calibration on the system. Using the average opacity from visible emissions observations conducted on the stack the baseline was established. Normal procedure would be to establish this as zero on a clear stack. The span value or slope was established by blocking the light source off. This is in accordance with established practice.

B. LINEARITY

Normal linearity tests are performed on a transmissometer with a dynamic zero and span. As this is a single pass instrument on an operating stack, this was not possible. After the preceding standardization procedure the test was conducted with the stack in operation. This is not proscribed procedure. It will only give relative results. If the in-stack opacity is reasonably stable an estimate of linearity is possible but it is not accurate. Linearity was tested by insertion of National Bureau Of Standards traceable neutral density filters into the light path. To assure that all of the light entering the photocell was attenuated, the filter was attached to the face of the photocell. Three filters were used with nominal opacities of 20,50, and 80%. To account for the variation in response due to stack opacity, multiple insertions of each filter were conducted.

C. INFRARED RESPONSE

Infrared response was audited by placing an infrared filter over the photocell in the system. This filter passes less than 3% of visible light. Thus the photocell output should be near zero or less than 5% of full output to indicate no infrared response.

D. ANGLE OF PROJECTION AND VIEW

Due to the inability to bench test the actual angle of projection and view, no actual figures are reported. However, extensive experience with similar systems and a careful visual inspection of the installation did give some information.

E. RESPONSE TIME

Response time was checked by timing the full scale response of the recorder while alternating turning the source on and off. Both upscale and downscale response were measured.

IV. AUDIT RESULTS

A. CALIBRATION

The calibration could not be accurately determined on the instrument at the time of the audit. Instead a relative calibration was performed without the actual zero value.

B. LINEARITY

The following table was developed from equations derived from the following relationship. It allows the establishment of a baseline within approximately 10% opacity. The average opacity can then be used in the same equation to estimate the response of thE meter to filter insertion with the baseline removed.

EQUATION 1

$$\frac{100-F}{100} \times \frac{100-E}{100} = \frac{100-T}{100}$$

WHERE F Filter value in % opacity
E Estimated opacity of stack in %
T Total measured opacity by meter in %

TABLE 1

ESTIMATION OF OPACITY FROM FILTER AND METER DATA

Data point	Opacity observed	Opacity filter	Trans. observed	Trans. filter	Trans. estimate	Opacity estimate
1	44	44	56	56	100	0 *
2	74	71	26	30	88	12
3	34	21	66	79	83	17
4	52	44	48	56	85	15
5	38	21	62	79	78	22
6	58	44	42	56	75	25
7	42	21	58	79	73	27
8	60	44	40	56	71	29
9	100	100	0	0	0	100 **
10	30	0	70	100	70	30
11	60	44	40	56	71	29
12	40	21	60	79	76	24
13	28	0	72	100	72	28
14	80	71	20	30	68	32
15	80	71	20	30	68	32
16	60	44	40	56	71	29
17	44	21	56	79	71	29

* Point taken prior to system stability
** Total light path blocked

Table 2 was developed from the data on table 1. It utilizes the average opacity of the stack as the baseline (E) in the equation to determine the effect of the filter and the linearity of the system.

TABLE 2

ESTIMATE OF METER RESPONSE TO FILTER INSERTION

DATA POINT	OPACITY OBSERVED	TRANS OBSERVED	OPACITY BASE	TRANS BASE	ESTIMATE RESPONSE	FILTER VALUE	
1	74	26	25	75	65	71	
2	34	66	25	75	12	21	
3	52	48	25	75	36	44	
4	38	62	25	75	17	21	
5	58	42	25	75	44	44	
6	42	58	25	75	23	21	
7	60	40	25	75	47	44	
8	30	70	25	75	7	0	*
9	60	40	25	75	47	44	
10	40	60	25	75	20	21	
11	28	72	25	75	4	0	*
12	80	20	25	75	73	71	
13	80	20	25	75	73	71	
14	60	40	25	75	47	44	
15	44	56	25	75	25	21	

* No filter inserted

Charts 1 and 2 illustrate the approach that was used. In chart 1 the actual response of the meter is plotted against the known filter value. The meter is set up with an upscale zero based upon visible emissions observations. Scatter is due to changing opacities in the stack. In spite of the scatter, the points indicate that the transmissometer is linear. In chart 2 the average of the estimated opacity values in table 1 (25) is used to calculate the estimated response with the upscale value calculated out. Once again the plot is linear and this time goes thru zero. This demonstration of the technique was based upon a quick evaluation of the stack opacity and is offered for demonstration purposes only.

CHART 1

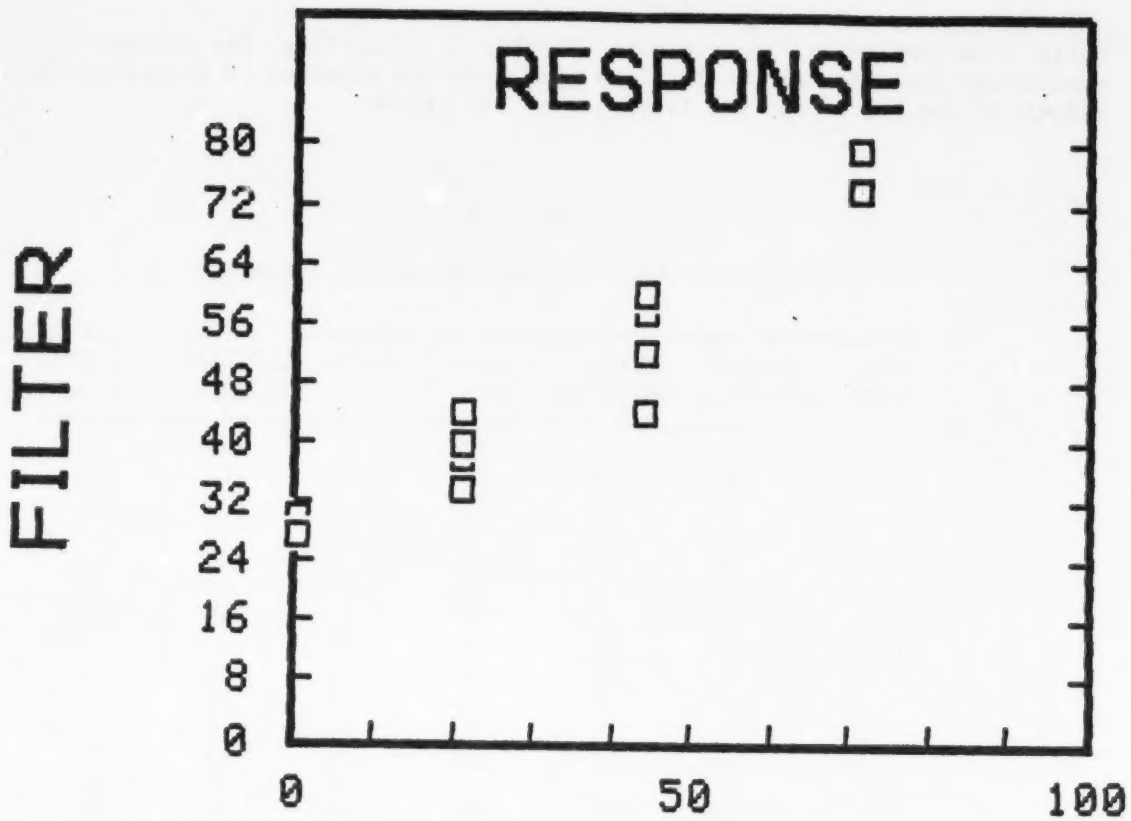
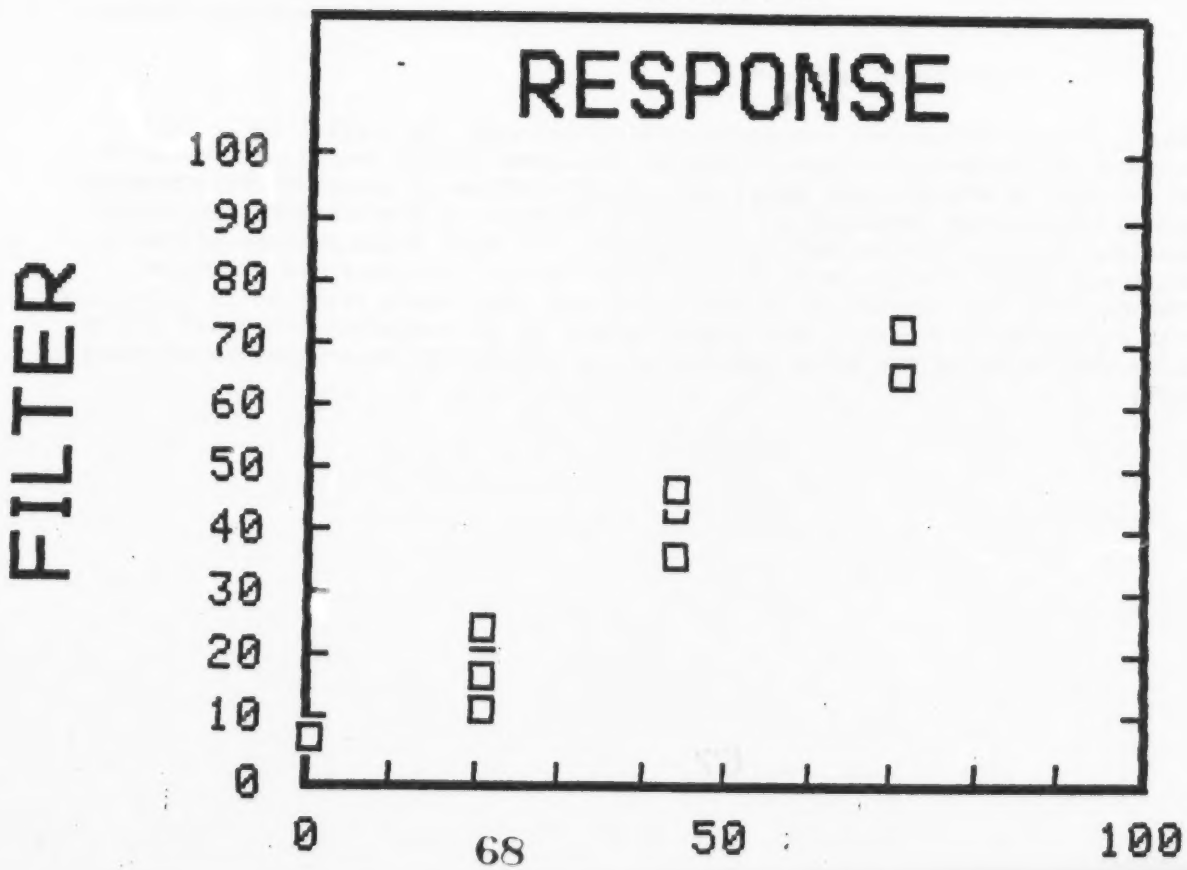


CHART 2



C. INFRARED AND PHOTOPIC RESPONSE SURVEY

The selenium detector used in the system is near photopic. That is it matches the photopic response curve of the human eye on the long wave end but not on the ultraviolet end. The infrared response test indicated that 5% or less of the response was due to infrared radiation. Considering the rough setup this is within acceptable limits.

D. ANGLE OF PROJECTION AND VIEW

The angle of projection and view were not accurately determined. However, the spotlight used as a source has a wide angle of projection and a more intense beam with a narrower angle. The sensitivity of the system to movement of the light indicates that the narrow beam has the greatest effect on the transmissometer. The photocell has a wide angle of view. There are no aperture plates to restrict the view of the photocell and prevent it from being negatively biased by scattered light.

E. RESPONSE TIME

The response time of the transmissometer is under 1 second for full scale response from either zero to 100 or 100 to zero. This results in a difficult to read strip chart. A response time of approximately 4 seconds would be more useful in this system.

F. SUNLIGHT INTERFERENCE

No appreciable interference from sunlight or ambient light was detected.

V. RECOMMENDATIONS FOR CALIBRATION/OPERATION OF PRESENT SYSTEM

Purchase 4 inch neutral density filters of nominal opacities of 20,50,and 80%. This is the equivalent of transmissions of 80,50,and 20%. For the purpose of calibrating this system gelatin filters available from a camera store would be adequate. Higher quality filters would be wasted.

PROCEDURE

1. Establish the span by use of a certified smoke reader and adjust the meter to that value by adjusting the sensitivity or photocell output.

2. Establish the transmission baseline by turning off the light source or blocking it. Adjust the recorder zero to just on scale.(a live zero)

3. Repeat steps 1 and 2 several times until consistent results are achieved.(no adjustment necessary)

4. With system on, insert the filters one at a time in the opening between the photocell and the stack, and record the results. Multiple insertions are highly recommended.

5. Perform a linear regression of the results but do not force it thru zero.

6. Alternately generate a calibration curve by compensating for the instack opacity by using equation #1. Results illustrated in table 2.

VI. RECOMMENDATIONS BOR REPAIR/MODIFICATION OF PRESENT SYSTEM

A. LIGHT SOURCE AND CONTROL SYSTEM

The light should be operated at its rated voltage to assure proper light wavelength emissions. This can be accomplished by installing a constant voltage (regulated) power supply for the light and checking that the light Voltage is correct with a meter at the light with the light on. Selection of the proper light and its associated voltage must be in conjunction with the proper output of the photocell.

B. PHOTOCELL

The photocell should be modified by the addition of an 102 filter available thru any retail camera store. A better solution would be to purchase a photocell with encapsulated filter. The photocell must be producing at least 25 millivolts with the selected light source to be linear. An aperture plate should be installed in the photocell housing to restrict the angle of view to at least 15 degrees preferably 10 degrees. This would result in the detection of less scattered light.

C. STRIP CHART RECORDER

The strip chart recorder does not need replacement. However it should be modified by installation of a 200 mfd 25 volt electrolytic capacitor in parallel with the input to the recorder. Additionally the recorder should be set up to measure transmission of light not opacity. Thus zero input would equal 100% opacity and 20 millivolts input would equal 0% opacity. This may require the adjustment of the alarm system but should cause little difficulty.

cell output millivolts	transmission	opacity
20	100%	0%
15	35%	25%
10	50%	50%
5	25%	75%
0	0%	100%

VII RECOMMENDATION FOR REPLACEMENT OF PRESENT SYSTEM

It is recommended that when the present unit is replaced, that the replacement transmissometer be a double pass instrument from one of the several major manufacturers. Additionally the purchase should include a full EPA performance test with a condition that payment be conditional to demonstrated compliance with all EPA requirements.

VISIBLE EMISSION OBSERVATION FORM 2

SOURCE NAME: STAMFORD MUNI. INCINERATOR
ADDRESS:
CITY: STAMFORD | STATE: CONN | ZIP:
PHONE: | SOURCE ID NUMBER:

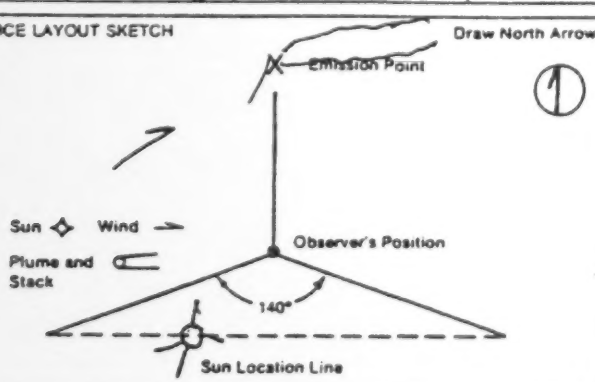
PROCESS EQUIPMENT: INCINERATOR | OPERATING MODE: FULL
CONTROL EQUIPMENT: ESP | OPERATING MODE: OK

DESCRIBE EMISSION POINT
START: Steel Stack | STOP: Steel Stack
HEIGHT ABOVE GROUND LEVEL: START: STOP: | HEIGHT RELATIVE TO OBSERVER: START: STOP:
DISTANCE FROM OBSERVER: START 450 STOP 450 | DIRECTION FROM OBSERVER: START N STOP N

DESCRIBE EMISSIONS
START: Coming | STOP: SAME
EMISSION COLOR: START Grey STOP Grey | PLUME TYPE: CONTINUOUS ☒ FUGITIVE ☐ INTERMITTENT ☐
WATER DROPLETS PRESENT: NO ☒ YES ☐ | IS WATER DROPLET PLUME: ATTACHED ☐ DETACHED ☐
POINT IN THE PLUME AT WHICH OPACITY WAS DETERMINED: START 5 Feet Above Stack STOP SAME

DESCRIBE BACKGROUND
START: CLEAR SKY | STOP: SAME
BACKGROUND COLOR: START Blue STOP Blue | SKY CONDITIONS: START CLEAR STOP CLEAR
WIND SPEED: START 5 STOP | WIND DIRECTION: START SW STOP SW
AMBIENT TEMP: START 85 STOP 85 | WET BULB TEMP: | RH, percent:

SOURCE LAYOUT SKETCH



COMMENTS: 22° Ambient

I HAVE RECEIVED A COPY OF THESE OPACITY OBSERVATIONS
SIGNATURE:
TITLE: DATE:

OBSERVATION DATE	START TIME	STOP TIME
07 24 85	1330	1336

SEC / MIN	0	15	30	45	SEC / MIN	0	15	30	45
1	10	10	15	25	31				
2	10	10	10	5	32				
3	10	5	10	5	33				
4	5	5	5	10	34				
5	10	5	5	5	35				
6	10	5	5	5	36				
7					37				
8					38				
9					39				
10					40				
11					41				
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25					55				
26					56				
27					57				
28					58				
29					59				
30					60				

RANGE OF OPACITY READINGS: MIN. 5 MAX. 25
HIGHEST AVERAGE OPACITY AND AVERAGING PERIOD: 8.3
NUMBER OF READINGS ≥ % → MINUTES OPACITY ≥ % × 0.25 =

OBSERVER'S NAME (PRINT): Thomas H. Rose
OBSERVER'S SIGNATURE: | DATE: 07 24 85
ORGANIZATION: Eastern Technical Associates
CERTIFIED BY: | DATE: 7/24/85
VERIFIED BY: | DATE: 7/24/85